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Evaluation of the Impacts of Turtle Excluder Devices (TEDs) on Shrimp Catch Rates in the Gulf of Mexico and South Atlantic, March 1988 through July 1989

BY

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Trained National Marine Fisheries Service observers collected information from March 1988-July 1989 on catch rates of shrimp and finfish from commercial shrimp vessels voluntarily participating in this study. Data were compared between TED-equipped nets (Georgia TED with and without an accelerator funnel) and standard shrimp nets. This represents partial fulfillment of OMB and House Appropriations Committee requirements with respect to TEDs and their economic impact on the shrimp fishery.

This report summarizes preliminary results through July 1989, including 4159 hours of fishing time. When the study is completed in September 1990, a comprehensive economic analysis will be completed with these data by Texas A&M University. Fishing areas, times and length of tows were controlled by the vessel captain. The catch rates of the vessels participating in the program were not significantly different than the catch rates of commercial shrimp fleets fishing in the same area during the same time frame. We feel that the results of this observer program are representative and meaningful in terms of the evaluation of TEDs under commercial conditions.

Standard and TED-equipped nets appeared to operate similarly with respect to types and frequency of problem tows. When problems with the fishing gear occurred, the TED-equipped nets lost more shrimp and finfish than standard nets.

Differences in the CPUEs between standard and TED-equipped

nets were compared using multivariate paired t-tests. Overall, a 10% loss of shrimp was experienced for quad-rigged vessels, whereas, the overall loss for twin-rigged vessels was about 2%. In general, for quad-rigged vessels, there were significant mean differences in the paired catch rates between the standard and TED nets for both shrimp and finfish. In all cases, the overall mean differences between CPUEs of standard and TED nets were positive, indicating the standard nets caught more shrimp and finfish than TED-equipped nets. The mean differences in the seasonal shrimp catch rates were less than 0.9 lbs/hr, without including trynet data and 1.4 lbs/hr with trynet catch added to the trailing net. Shrimp CPUEs ranged seasonally from a gain of 0.1 lbs/hr to a loss of 1.4 lbs/hr. CPUEs vary seasonally and only during the winter months were there no significant differences in the overall shrimp catch rates between standard and TED-equipped nets; during all other seasons, differences were significant. The overall finfish CPUEs were 74.0 and 64.5 lbs/hr for standard and TED nets, respectively, or a mean difference of 9.4 lbs/hr.

Significant differences were noted between the shrimp catch rates of the two TED types. When the Georgia TED without a funnel was compared with a standard net, the catch rate for the standard net was 7.2 lbs/hr and 5.9 lbs/hr for the TED-equipped net, or a difference of 1.3 lbs/hr. The Georgia TED with the funnel caught 5.9 lbs/hr compared to 6.7 lbs/hr for the standard net, or a difference of 0.7 lbs/hr.

For twin-rigged vessels, the overall shrimp CPUE with TED-equipped nets ranged from 2% better than the standard net to 18% worse than the standard nets with a trynet adjustment. No significant difference was observed in the overall catch rates between TED and standard nets for twin-rigged vessels.

Yield was modelled to determine what impact various levels of shrimp loss would have on the overall population. Overall decrease of 10% in fishing mortality rate resulted in no detectable change in the overall yield of both brown and white shrimp fisheries and a 2% decrease in the yield for the pink shrimp fishery.

A total of 40 turtles were caught in the observer program, of which 27 were caught along the Atlantic coast and 13 were caught in the Gulf of Mexico. Nine of the 40 turtles came aboard unconscious and 36 were released alive. The estimated total capture of turtles using 1988 fishing effort is 14,112 for the Gulf of Mexico and 14,986 turtles for the Atlantic Ocean. The capture rate of sea turtles in the Gulf of Mexico was similar to earlier studies, but apparently declined in the Atlantic.

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INTRODUCTION

The National Marine Fisheries Service (NMFS) promulgated regulations which required the use of Turtle Excluder Devices (TEDs) on offshore shrimp vessels beginning in June 1987 (Federal Register, 1987), depending upon vessel size, geographic location, and fishing area. Due to a series of judicial, Congressional and administrative actions, TED regulations were not fully implemented region-wide until May 1, 1990.

Both the Office of Management and Budget (OMB) and the House Appropriations Committee in 1988 required certain studies and reports relating to TED use and testing and evaluating the impacts of TED use on fishermen and sea turtles. The OMB required a study on whether or not TEDs are effectively excluding turtles and the House Appropriations Committee required a study on the full economic impact of TEDs. This report is in partial fulfillment of both those requirements. NMFS, in cooperation with the shrimp industry, initiated a TED Evaluation Program on March 5, 1988. The overall goal of this program was to determine the impacts of the utilization of certified TEDs on commercial shrimp trawlers operating on the South Atlantic and Gulf of Mexico coasts. Funding was provided by NMFS, the Marine Fisheries Initiative program (MARFIN), and the Gulf and South Atlantic Fisheries Development Foundation.

This program, initiated in March 1988, will continue through September 1990. We are reporting on observations from March 1988 through July 1989. The program is aimed at comparing shrimp catch rates of TED-equipped trawls with those of standard trawls without TEDs in selected shrimp fishing areas of the southeast region. For this purpose, trained observers were placed on shrimp vessels operating off the coasts of Texas, Louisiana, Mississippi, Alabama, Florida (Gulf and Atlantic), Georgia and South Carolina. Results will be used in a comprehensive economic analysis of the impact of TEDs on the shrimp industry which is currently being conducted by Texas A&M University. The analysis should be available by the end of this year.

Specific objectives of the TED evaluation program are to:

1) Compare catch rates of shrimp for TED-equipped trawls and standard trawls without TEDs in representative shrimp fishing areas of the Gulf and Atlantic coasts of the U.S. by season,

2) Provide data, results and a biological simulation model to the Economics Analysis Branch of the NMFS for an economic evaluation of impacts of TEDs.

MATERIALS AND METHODS

Recruitment of Vessels

Vessels were recruited through the assistance of NMFS port agents, NOAA Sea Grant Marine Advisory Agents, regional shrimp associations and industry contacts. Participation in the study by shrimpers was strictly voluntary. Vessels and crews were not government leased or chartered. A payment of $100/day was sometimes provided by the Gulf and South Atlantic Fisheries Development Foundation, generally when TEDs were not required by law. This was an incentive for vessel owners to allow NMFS personnel to collect data while on board their vessels. All participating vessels had appropriate federal authorization to use TEDs in one-half the trawls when a NMFS observer was on board. Eighteen shrimp vessels used in the study were quad-rigged (two trawls towed on each side), and one was twin-rigged (one trawl towed on each side). Analyses of data from quad-rigged and twin-rigged vessels will be discussed separately.

Positioning of Net Types

Trips were designed initially to have a TED-equipped net paired with a standard net on each side of the vessel. The assignments of TEDs to inboard or outboard positions were made with the assumption that these positions would be reversed on subsequent trips. Several vessels refused to participate unless we placed the TEDs in certain configurations. Consequently, we have recorded almost every possible TED and standard net position configuration.

Identification of Study Sites

Initially, observers were placed on shrimp vessels in each of the four major Gulf of Mexico offshore fishing areas: Louisiana, Texas, south Florida, and Alabama-Mississippi. Of 600 planned observer days, 240 were scheduled for Louisiana, 200 for Texas, 100 for Florida and 60 for Mississippi-Alabama. The respective percentages of combined five year (1981-1986) shrimp landings from these fishing areas were 49%, 33%, 10%, and 8%. We intended that areas with higher production be allotted greater amounts of observer effort, although not necessarily in direct proportion to production. Planned observer effort was increased somewhat in Alabama-Mississippi and in the primarily hard bottom south Florida area to provide sufficient data for statistical analysis of TED performance under the special conditions encountered in these areas. One hundred observer days were also scheduled for the South Atlantic. Observer days were targeted for the peak regional shrimping seasons in each area.

The study depended on shrimpers volunteering to let NMFS personnel collect data on board their vessels. Due to limited response by shrimpers, we collected data from virtually any vessel whose owner or captain would allow us aboard. Since one of the principal objectives of this study was to evaluate the effect of the use of TEDs on commercial shrimping, the shrimpers decided where and when to fish and which certified TED to use.

Our only NMFS stipulations were that the shrimper had to use federally approved TEDs and to keep catches from each net separated from each other.

Observer Training

All observers were required to have at least a bachelors degree in science and some college course work in biology. The observers received general training in the form of:
1) presentation of background information on TED research, 2) review of TED Regulations, 3) review of diagrams of trawls and TED's, 4) discussions on how changes in trawling gear affect the fishing configuration and shrimp catchability of trawls (published material also provided for reference), 5) discussions of general procedures for the TED study, 6) review of diagnostic keys for identification of sea turtles, shrimp and fish 7) review of detailed instructions for filling out all data sheets, 8) discussions of the most common errors made on data sheets and how to avoid them, and 9) presentations of the guidelines for summarizing data into trip reports and trip summaries for outside circulation. Approximately 12 hours of video tapes were utilized to familiarize observers with sea turtle biology, shrimp trawling activities, terminology of trawling gear, effects of gear alterations on shrimp catchability of trawls, a variety of TEDs, installation procedures for TEDs, the performance of TEDs underwater and a special video showing all of the required procedures for data collection.

Observers also received two to three days of intensive training aboard shrimp vessels. This included all procedures necessary to collect data and fill out data sheets properly. A review of the identification of shrimp and fish species was also made at this time. After their training was completed, observers were dispatched from the NMFS Galveston Laboratory to commercial shrimping vessels working off the coasts of South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas.

Gear Tuning and Control Tows

The fishing efficiency of all nets used in this study was standardized by NMFS or Texas A&M Sea Grant gear specialists during a participating vessel's initial trip. Control tows were made using standard nets which were adjusted to catch approximately equal amounts of shrimp. Vessel captains were briefed by gear specialists about the proper installation of TEDs. Once TEDs were installed, the gear specialist made necessary modifications to the rigging for the proper operation of the TED, based upon his experience and observation of similar catch rates between standard and TED-equipped nets. This procedure was usually accomplished in 2-3 days. The captain was responsible for gear tuning after the departure of the gear tuner. Variation in the tuning ability of captains can contribute to variation seen in the TED data.

Data Collection

Every phase of the operation was explained to captains to insure that they understood exactly what data NMFS needed to collect. Otherwise every effort was made to minimize the observers influence on normal fishing activities. The primary requirement was that catches from each net be kept separated from all others so the total weight of shrimp from each trawl could be recorded. Captains of the vessels were requested to examine the data collected by the NMFS observer and to sign the data sheets to verify their accuracy. Copies of the completed data sheets were mailed to the vessel captain and owner for their record.

Shrimp. If necessary, the back deck of the vessels was partitioned into sections with wooden beams to prevent the catches of the trawls from mixing. A sample of approximately 50 pounds was shovelled from the contents of each trawl into standard sized plastic shrimp baskets (70 lb capacity). Thus a quad-rigged vessel produced four samples per tow and a twin-rigged two samples per tow. Shrimp and fish were separated from each sample. The total weight (to the nearest lb) of brown, pink, and white shrimp (*Penaeus sp*.) combined was recorded for each net for each tow. Another weight was recorded for each additional commercial shrimp species. In order for total weights to be standardized, the observer noted catch as heads on or heads off.

For each net the number of shrimp (heads on) in approximately 5 lb of the basket sample was recorded. Observers were instructed in selecting a representative group of shrimp that was not biased according to shrimp size. In those cases in which the shrimper discarded small shrimp, procedures were modified to include only the size range of shrimp retained by the shrimpers.

For one tow each day, total length (length from tip of rostrum to tip of telson) in mm was measured for a representative sample of 200 shrimp. Fifty shrimp came from each net if the vessel was quad-rigged or 100 shrimp from each net if the vessel was twin-rigged. Shrimp with broken telsons, broken tails, broken rostrums, and crushed shrimp were not measured. These samples included all sizes of shrimp captured by the trawl including the size ranges not kept by the shrimper.

Commercial Shrimp Catch. Catch per unit effort (CPUE) in lbs/day, heads off, from NMFS port agent interviews of the shrimp fishery were compared with CPUE data from our observer trips. These comparisons were used to determine the similarity between this study's CPUEs and those reported by the commercial fleet from the same areas and times.

Fish. The most abundant finfish species was inferred for each trawl by casual observation. A group weight was recorded for the fish sorted from the basket sample taken from each trawl. For each trawl, a combined weight was recorded of all fish too large to fit into the basket. Since the total weight of shrimp was also recorded for each trawl, the total weight of fish per trawl could be estimated assuming direct proportion:

$$F_T = \{ (F_S / S_S) \times S_T \} + F_L$$

where,

F_T = estimated total fish weight, F_S = sample fish weight, S_S = sample shrimp weight, S_T = total shrimp weight, and F_L = combined weight of fish too large to fit in basket.

Once each day (usually the last tow), finfish in basket samples taken from one TED-equipped and one standard trawl were sorted by selected species, counted, and weighed by species. The selected species included Atlantic croaker, spot, seatrout (all species), longspine porgy, flounder (all species), snapper (all species), mackerel (all species), redfish and grouper (all species). All other fish species were weighed together as a miscellaneous category. Beginning in mid-1989, additional MARFIN funding allowed for increased fish sampling aboard some Gulf of Mexico vessels. Once each day, every fish in the basket sample taken from each trawl of a given tow was measured and identified to species.

<u>Sea Turtles.</u> For each turtle caught, the date, location, depth of capture, type of net (TED-equipped, standard or try net), species, length (straight and curved), width (straight and curved), weight (if possible), and condition (conscious, unconscious, fresh dead, dead but not fresh) were recorded. All turtle sightings were also noted. Dead turtles were 1) marked with spray paint, flipper-tagged and returned to the sea for possible return through the sea turtle stranding and salvage network (STSSN) or 2) returned to the laboratory for autopsy. Living turtles were flipper-tagged and released.

Other Catch. For each trawl a group weight was recorded for each species (other than commercial shrimp) which was retained aboard for consumption or sale. This included catch such as lobster, stone crab, blue crab, red snapper, flounder, etc. When a species was arbitrarily removed from one trawl but also appeared in other trawls, or if it was not possible to determine which trawl the catch came from, then the group weight was recorded for all trawls combined.

Tow Duration. Tow duration was defined as the time the brake was set on the winch at the beginning of the tow to the time when the winch was engaged and the brake released to retrieve the trawl from the bottom.

Bottom Type. Bottom type was characterized as rough or smooth and hard or soft. If nets were snagged or torn, then the bottom was considered rough. A smooth bottom, such as mud or shell hash, had little or no topographic relief and would not snag or tear nets. When in doubt, the vessel captain was consulted. Hard bottom was defined as any bottom other than mud, and mud was considered soft bottom.

TEDs and Trawling Equipment. TEDs were characterized as to type, panel bar spacing, presence or absence of an accelerator funnel (Appendix III, Figure 1), size of opening to exclude turtles, etc. In some areas, when TEDs were repeatedly bent during fishing activities new TEDs constructed from larger gauge pipe were purchased to minimize the problem. Prior to making experimental tows, a variety of measurements such as length of headrope and footrope, lazy lines, leglines, size of trawl mesh and other data were recorded to characterize each trawl. This allowed for the standardization of shrimp and fish catch between vessels using different sizes of gear. If a trawl was later modified by captain or crew, the modifications were also recorded.

Gear Performance. Each net was characterized by an operation code based on its performance in the water (Appendix II, Table 1). A net towed without incident was coded 'Z'. Other codes were used to describe any problems encountered, such as tangling of trawl doors, the cod end bag coming untied, etc. Two codes were occasionally required to describe trawl performance.

Information on debris clogging the TEDs was recorded. Debris was defined as items that were caught in the trawl which required special effort to remove and/or discard. Some of these included large loggerhead sponges, tree trunks or branches, tangled cable, lobster pots, and TV sets.

Not all data were used in the analyses of shrimp and fish catch. Data from nets with operation codes A, B, C, E, F, L, M, O, S and Z and combinations were used for analyses. Codes D, G, H, I, J, K, N, P, Q, R, T and U reflect uncollected data or non-TED related problems affecting catch so these data were not used in analyses.

Seasons. For analytical purposes seasons were defined as winter (DEC-FEB), spring (MAR-MAY), summer (JUN-AUG) and fall (SEP-NOV).

Statistical Analyses

Multivariate Analyses. Multivariate paired t-tests were performed on paired data to test the null hypothesis of equal catch per unit effort (CPUE, lbs/hr) for shrimp and finfish simultaneously for both the standard and TED-equipped trawls. Data were paired either by tow or by trip for quad-rigged and twin-rigged vessels for these analyses. This test is discussed in detail by Morrison (1976). The null hypothesis was:

$$H_o = \begin{pmatrix} \mu_{\textbf{diff shrimp}} & = & 0 \\ \mu_{\textbf{diff fish}} & & 0 \end{pmatrix}$$

Univariate adjusted paired t-tests were performed whenever the above null hypothesis was rejected. Also, the confidence intervals on each of the parameters (stated in the above null hypothesis) were constructed.

General Linear Model Analyses. General linear model (GLM) analyses were performed on four data sets, including quad-rigged and twin-rigged vessels, each with TED-equipped and standard trawls paired by tow and by trip using SAS™, (Statistical Analysis System, SAS Institute, Inc., Cary, N.C.). The GLM was used to compare standard and TED-equipped nets. The dependent variables used in the GLM analyses included differences between standard and TED-equipped nets for catch, ln(catch), CPUE and ln(CPUE), ratios of catches and CPUEs in TED-equipped and standard nets and the logarithmic transformations of these ratios and shrimp loss (gain) rates in TED-equipped nets as compared to standard nets.

Milliken and Johnson (1984) discussed GLM methods, underlying assumptions, problems and interpretations for unbalanced experiments in multiway treatment structures with missing data such as the paired data from the TED evaluation study. A discussion of the GLM methods, assumptions and analyses used in this study is included in Appendix I.

Additional Analyses. Other statistical analyses of the data included frequency distributions, correlations, linear regressions, t-tests and paired t-tests, mean, standard deviation, confidence intervals and other descriptive statistics (Sokal and Rohlf, 1981).

Biological Models. Deterministic population models were produced for all three shrimp species by linking a Ricker-type yield per recruit model to recruitment estimates that were independent of parent stock (Ricker, 1975; Nichols, 1984; Nance and Nichols, 1988). Recruitment level was set at the geometric mean for the 1960-1988 period. Averages of estimates for 1985-1988 fishing mortality (F) derived from virtual population analysis were used as the baseline for current conditions. Yield estimates were made for all three species for a range of "F-multiplier" values ranging from 0-2 by 0.002 increments. Tables of these yield estimates were used to determine effects of TED equipped nets on the overall shrimp yield in the Gulf of Mexico.

This was possible because yield estimates (Y_t are a direct result of fishing mortality rates (Royce, 1972). The yield model was:

$$Y_t = F_t \, N_t \, W_t \, dt$$

where,

N_t is the number of animals (R) in a cohort subject to fishing (F) and natural (M) mortality at a given time (t), the formula is:

$$N_t = Re^{-(F + M)(t-t_0)}$$

F_t is the fishing mortality at a given time

W_t is the average weight of an individual at time t, estimated from growth equations.

Fishing mortality rate (F) is the product of two separate variables; i.e., a catchability coefficient (q) and directed nominal fishing effort (f).

$$F = q \, f$$

TED-equipped nets influence fishing mortality by affecting shrimp catchability and not fishing effort (f). Any percentage change in shrimp catchability caused by TED-equipped nets is assumed to be directly reflected by an equal percentage change in fishing mortality. This is based on an assumption of direct proportionality between change in CPUE and change in q. Thus, any change in CPUE as a result of TED use is translated into a proportional change in q.

RESULTS

Descriptive Data Summary

Trips. For each geographic area, the frequency of trips is shown by season (Figs. 1 and 2). Of 32 trips in the Gulf of Mexico, 27 trips employed Georgia TEDs equipped with accelerator funnels and 5 trips employed Georgia TEDs without funnels. This contrasts with the Atlantic coast where funnels were used on only 1 trip of 16. Most trips occurred during the summer which, along with the fall, is generally considered part of the peak shrimping season in all areas except southwest Florida where highest shrimp production occurs during winter and early spring. In the Gulf of Mexico, 11 trips were made during summer, 8 in fall, 7 in winter and 6 in spring. In the Atlantic, 12 trips were in the summer and 4 in winter. The Morrison "Soft" TED, a NMFS-type TED, and a homemade TED were used on a limited number of trips; however, sample sizes were not large enough for analysis.

A twin-rigged vessel was only used in Texas. Three twin-rigged trips were made during the fall and winter using the Georgia TED without a funnel. Four trips were made in the fall using a Georgia TED with a funnel.

Paired Data. When at least one TED-equipped net and one standard net were towed simultaneously from a given vessel, the resulting data were considered to be a valid pair. In cases where two or more of either net type were towed, the data from the like nets were averaged to create a single standard-TED pair.

During one trip, Georgia TEDs with and without funnels were towed simultaneously. For this trip and for each tow, one of the two TED-equipped nets was randomly selected along with a randomly selected standard net to make a pair. Two artificial "sub-trips" were created from the original trip - one contained the Georgia TEDs with funnels and the other included Georgia TEDs without funnels. Figures 3 and 4 show the frequencies of TED-standard data pairs with usable operational codes by geographic area and season.

In the Gulf of Mexico, information from 488 data pairs (quad-rigged and twin-rigged combined) was collected from tows using Georgia TEDs equipped with accelerator funnels, and 61 pairs without funnels. There were 22 data pairs in the Atlantic for Georgia TEDs with accelerator funnels and 231 without funnels. In the Atlantic, approximately 67% of the sampling was during summer and the remainder during winter.

About 8% of the data pairs by tow were collected from a twin-rigged vessel operating off the Texas coast. Thirty-six data pairs by tow were collected in the fall for Georgia TEDs equipped with funnels. Twenty-three data pairs were collected during fall and 5 during winter for tows using Georgia TEDs without funnels.

<u>Performance of TED-equipped and Standard Nets.</u> The total number of nets towed was 3,808; 3640 tows on quad-rigged vessels and 168 tows on twin-rigged vessels. Standard nets and nets equipped with Georgia TEDs, with and without funnels, composed

3,641 of the 3,808 tows. The frequency of net tows (quad- and twin-rigged vessels combined) with each operation code was tabulated by TED type (Appendix II, Tables 2 and 3). Percentage of successful tows, those with no gear-related problems attributable to TEDs (Table 1) was similar between standard and TED-equipped nets. About 93.7% of all standard net tows, 91.1% of all net tows of Georgia TED-equipped nets without funnels, and 89.8% of all net tows of Georgia TED-equipped nets with accelerator funnels were successful (Table 1). Thus the differences in success between standard nets and TED-equipped nets with and without funnels are 3.9% and 2.6% respectively. Operation codes not included as successful represent tows with problems that <u>may or may not</u> be associated with the presence of TEDs. This represented only 6.3%, 8.9% and 10.2% of the net tows for standard nets, Georgia TED-equipped nets without funnel, and Georgia TED-equipped nets with funnel, respectively.

Operation code frequencies of net tows for TED-equipped and standard nets were similar in all cases except for net tows with codes F and O. One percent of standard net tows were coded F (gear fouled, typically entangled in itself) compared with 5.1% of net tows using Georgia TED-equipped nets without funnels and 1.3% of net tows using Georgia TED-equipped nets with funnels. Code O (gear fouled on object or object caught in net) occurred in 0.7% of standard net tows, 0.02% of net tows of Georgia TED-equipped nets without funnels, and 2.7% net tows of Georgia TED-equipped nets with funnels. Based on operation codes, it appears that the percentages of successful tows were very similar between standard nets and nets equipped with Georgia TEDs with or without funnels.

<u>CPUE Comparisons with the Commercial Fleet.</u> Average CPUE of shrimp calculated on a trip by trip basis for standard nets monitored on commercial vessels participating in the TED observer program was compared to CPUE for standard nets on other commercial vessels fishing in the same areas and time. Information on non-participating commercial vessels was obtained through interviews by NMFS port agents. Values were summarized by season and statistical subarea (Table 2, Appendix III, Figure 2). Standard net CPUEs of commercial vessels with observers were not significantly different (P = 0.65) from CPUEs on other commercial vessels. In four of seven cases, overall shrimp catch from standard nets on TED observer vessels had a higher CPUE than standard nets on other commercial vessels. Four of the comparisons ranged between -4.0 and +8.2 lb per hr and three comparisons were within 1.5 lb per hour (Table 2). It is felt that TED observer vessels were representative of other commercial vessels in the fleet fishing in similar places at the same time.

<u>Correlations</u>. There were significant correlations between standard and TED-equipped nets paired by tow (all areas, seasons, and vessels; Appendix II, Tables 4 and 5) with respect to shrimp catch, shrimp catch adjusted for try net catch, shrimp CPUE and shrimp CPUE adjusted for try net catch (Figs. 5-8). Correlation coefficients ranged from 0.91 to 0.95. No apparent differences

were observed among areas, seasons and vessels (quad-rigged or twin-rigged).

Within standard and TED-equipped nets, significant correlations were present between shrimp catch rates and fish catch rates (pounds/tow and CPUEs) both for data adjusted with try net catch and data not adjusted with try net catch (Figs. 9 and 10; Appendix III, Figs. 2-8). The adjustment for try net catch was made by adding the shrimp weight (heads off) from the try net to the shrimp weight (heads off) of the inboard net towed on the same side as the try net. Although significance was probably due to the large sample sizes, the small r values ranged from 0.10 to 0.17.

Multivariate Paired T-test

Multivariate Paired t-test for Quad-rigged Vessels by Tow. A multivariate paired t-test discussed by Watson et al. (1986) was used on data paired by tow to compare TED-equipped and standard nets with regard to shrimp and finfish CPUE. The data collected for TED-equipped and standard nets during different seasons, areas and TED types provide strong evidence to refute the null hypothesis of no difference between the CPUE for shrimp and finfish in standard versus TED-equipped nets. The differences tested simultaneously for finfish and shrimp (Tables 3 and 4) were significant at P values usually much less than 0.01. The P value is the probability of obtaining differences at least as large as the observed difference between CPUEs of TED-equipped and standard nets when the null hypothesis is true. P values less than 0.05 are judged to be indicative of significant difference. Significant mean differences were observed not only when viewing the simultaneous comparisons of catch rates of TED-equipped and standard nets overall, but also for different months, areas and times (day/night combinations). The only exception was found during the winter period. However, rejection of the null hypothesis does not indicate which of the two mean differences, that for shrimp or for fish, have caused rejection of the null hypothesis. The same methodology used by Watson et al. (1986) and discussed by Morrison (1976) to control experimental error rate was used here to test for shrimp and finfish mean differences between the standard and TED-equipped trawls separately. When viewing only the mean difference in CPUE for shrimp, there were significant mean differences between TED and standard nets for most comparisons. The only exceptions were for the winter period, areas 9-12, statistical area 28 and combined day and night trawls. This indicates that there was usually a significant mean difference in shrimp CPUE between standard and TED-equipped nets during most fishing operations regardless of the TED type.

For the Gulf and South Atlantic combined, mean differences of shrimp catch rate between standard and TED-equipped nets appear to be slight; 10% overall for quad-rigged vessels and 2% for twin-rigged vessels. The mean differences range from 0.5 to 0.9 lb per hour of fishing without including trynet catch. Mean differences ranged from 0.7 to 1.3 lb per hour of fishing when trynet catch was included. When adjustments for try net catch were not included in the analysis, Georgia TEDs with funnels lost an average 0.5 lb of shrimp per hour as compared to standard nets and Georgia TEDs without funnels lost an average 0.9 lb of shrimp per hour as compared to standard nets. Likewise, the mean difference in the catch rates of finfish was significant between the standard and TED-equipped nets, primarily due to a lower catch rate for TED-equipped nets as compared to standard nets. The finfish CPUE mean differences between TED-equipped and standard nets ranged from 8.3 to 11.5 lb per hour. Although this is a small mean loss, it clearly shows a significant reduction in the finfish by-catch with the Georgia TED either with or without a funnel.

All shrimp vessels normally fish with a try net in front of one of their nets. In this volunteer study the positioning of the nets was not directed by NMFS; therefore, the number of times the try net would be positioned in front of a standard or a TED-equipped net was not randomly determined. In reviewing all of the data, of a total of 877 paired tows in which a try net was involved, 664 (76%) of these had the try net positioned in front of the standard net, while only 213 (24%) were positioned in front of the TED-equipped net (Table 5).

Try net catch was added to the net directly behind it. Therefore, in 76% of the cases the catch was added to the standard net and in only 24% of the cases was it added to the TED-equipped net. Since these are quad-rigged vessels, it is probably inaccurate to assume that all of the catch caught by the try net would go into the net immediately behind it. Most likely, were the try net not present, some of the shrimp would have been captured by the outboard net. Therefore, we also compared the mean CPUEs without try net catch added in for standard and TED-equipped nets. Table 6 describes this relationship. When the try net was in front of the standard net, the mean catch rate of shrimp was 6.9 lbs per hour. However, the catch rate for TEDs with and without funnels was the same, 5.9 lb/hr with or without try net in front of the TED-equipped net. This shows that the try net had an effect of at least 6% (on the average) on the catch rates of shrimp in the standard net, therefore, corrections based on try net data increased the difference between the standard and TED in all cases.

The mean difference in shrimp CPUE between TED-equipped and standard nets (Table 7) was greater when there were problems with the nets during a tow, than when there were none (1.4 lb vs 0.4 lb). This was also true for fish CPUEs (16.7 lb vs 7.3 lb). Similar results were found when try net catches were added to the inboard nets directly behind them.

<u>Multivariate Paired t-tests for Quad-rigged Vessels by Trips.</u> Multivariate paired t-tests for quad-rigged vessels were also conducted by trip. Results are listed in Tables 8 and 9. In contrast to the analysis by tows, significant differences were the exception rather than the rule. When try net adjustments were not included, the overall CPUE mean difference between

standard and TED-equipped net was significant for both shrimp and fish. However, one TED type (Georgia TED without a funnel) showed a significant difference overall for shrimp alone as well as fish alone, whereas the Georgia TED with a funnel had no significantly different CPUE values. Thus, the null hypothesis of no difference was not rejected for this TED type. There were virtually no significant differences for shrimp CPUE by season (except for summer) nor area except for statistical areas 30-32. There were slightly different results when the try nets were included in the analysis. Significant mean differences were noted overall and by all TED types used.

Generally, the shrimp catch rate mean differences between standard and TED-equipped nets were slight; without try nets the mean differences ranged from 0.4 lb to 1.0 lb per hour and when try net adjustments were included the mean differences ranged from 0.7 lb to 1.2 lb per hour. Mean differences in the catch rates of shrimp between the standard nets and TED-equipped nets without funnels were the highest whether or not the try net adjustment was included. Conversely, mean differences in catch rates between standard and TED-equipped nets for the Georgia TED with a funnel were 0.4 lb per hr without try net adjustment and 0.7 lb per hr with try net.

The mean differences in the catch rates of finfish were also apparent when each TED type was compared to standard nets (a difference of 3.9 lb per hour for Georgia TEDs with a funnel compared to 12.0 lb per hour for Georgia TEDs without a funnel).

The TED-equipped net with funnel did not significantly reduce the mean CPUE as compared to the standard net. However, TED-equipped nets without funnels did reduce CPUE significantly.

Multivariate Paired t-tests for Twin-rigged Vessels by Tow. In contrast to the analysis performed for quad-rigged vessel tows, significant mean differences were the exception rather than the rule on the twin-rigged vessel (Table 10). One TED type (Georgia TED without a funnel) showed a significant mean difference overall, for shrimp alone, but not for fish alone. The other TED type (Georgia TED with a funnel) had no significant mean difference between CPUE values. There were no significant mean differences overall, or for areas, month or day/night combinations.

Shrimp catch rate mean differences between standard and TED-equipped nets ranged from negative 0.2 lbs per hour to 1.4 lbs per hour. The Georgia TED without a funnel had the greatest mean difference in catch rates.

Fish catch rate mean differences between standard and TED-equipped nets were all less than ± 1.0 lb per hour. No significant mean difference in fish catch between net types occurred in this analysis.

General Linear Model Analyses

Paired Data. General linear model (GLM) analyses were performed on paired data for standard vs TED-equipped trawls (Appendix I, Tables 1-4). The four data sets analyzed were the same as those in the multivariate paired t-test and were represented by combinations of quad-rigged and twin rigged trawlers, with TED-standard net pairings by tow and by trip. In some cases, the great imbalance of the data sets (Appendix I, Table 1) prevented evaluation of the effects of Region (R) or Season (Q), but the effect of TED type (T) could be evaluated in all four data sets (Appendix I, Tables 3 and 4). A complete description of the variables, analyses, assumptions and results is found in Appendix I.

Two sets of GLM analyses, one with and one without adjustment for try net catches of shrimp (Table 11), used as dependent variable the difference between natural logarithms of shrimp catches in standard and TED-equipped trawls. In these analyses, the independent variables and interactions in the GLM accounted for greater proportions of variation in the dependent variable than in the other models we tested (see Appendix I, Table 3).

For all models tested, the residuals had a mean of zero, thus fulfilling one assumption of the analysis (Appendix I, Table 3). However, those in which the difference between logarithms of catches was used as the dependent variable (i. e. those with high coefficients of determination) produced low coefficients of skewness and kurtosis for the residuals, thus closely approximating the additional assumption of normality of residuals required for GLM analysis (Table 11). Among these models, those in which region was the classification variable produced the highest coefficients of determination, followed by those in which season was the classification variable, and finally by those in which TED type was the classification variable (Table 11). This indicated that more variation in these dependent variables was accounted for by region than season, and more by season than TED type.

Quad-rigged Trawl Data Paired by Tow. When the Least Squares Means (LSMs) of these best dependent variables for quad-rigged trawlers with data paired by tow were tested to determine whether they differed from zero, the LSMs for the difference between logarithms of shrimp catches were not significantly different from zero for Georgia TEDs without funnels, for regions 18-21, 1-8, and >21, and season (Table 12). Still fewer LSMs were not significantly different from zero when the try net adjustment was applied, including those for regions 9-12, 1-8 and >21, and seasons spring and fall. Thus, the adjustment for try net catch affected the results of the comparison between the logarithms of shrimp catch in standard and TED-equipped trawls by reducing the number of cases in which LSMs were significantly different from zero.

Quad-rigged Trawl Data Paired by Trip. For quad-rigged vessel data paired by trip, LSMs of the difference between logarithms of shrimp catches were not significantly different from zero for regions 9-12, 1-8 and >21 and seasons winter and spring (Table 12). The LSM for fall was not estimable due to data imbalance.

Twin-rigged Trawl Data Paired by Tow. For twin-rigged vessel data paired by tow, the effects of region and season could not be tested by GLM due to data imbalance, so only TED type was used as a classification variable (Table 11). For data paired by tow, the LSMs of the difference between logarithms of shrimp catches were not significantly different from zero for both TED types when there was no adjustment for try net catch of shrimp, and the LSM for Georgia TEDs with funnels did not differ significantly from zero when the try net adjustment was made (Table 12).

Twin-rigged Trawl Data Paired by Trip. For twin-rigged vessel data paired by trip, none of the LSMs for differences between logarithms of shrimp catches differed significantly from zero for the two TED types, both with and without the try net correction (Table 12).

Quad-rigged vs Twin-rigged Vessels. General results for twin-rigged trawls paired by tow and for both quad-rigged and twin-rigged trawls paired by trip undoubtedly were affected by the smaller sample sizes (Appendix I, Table 1). Also the sampling unit in the study was the tow. Therefore, GLM analyses of data paired by tow should be considered superior to those for data paired by trip.

Overall. In no cases were the negative LSMs (i.e. those suggesting a gain in natural logarithm of shrimp catch by TED-equipped trawls) significantly different from zero (Table 12).

Turtle Captures

Forty sea turtles (alive or fresh dead) were captured on vessels participating in this study. They consisted of 32 loggerheads (Caretta caretta), 6 Kemp's ridleys (Lepidochelys kempi), and 2 hawksbills (Eretmochelys imbricata). Thirty-five were caught in standard shrimp trawls, 4 in try nets and 1 in a TED-equipped trawl (Table 13, Fig. 11). Refer to Appendix III (Figs. 9-12) for the seasonal breakdown of turtle captures. The loggerhead caught in the TED-equipped trawl was entangled in the accelerator funnel. It was subsequently tagged and released alive. Four of the turtles (2 loggerheads, 1 Kemp's ridley and 1 hawksbill) captured in standard shrimp trawls could not be revived after several hours of resuscitation and were presumed dead. Three of these were painted and thrown overboard. One loggerhead was autopsied within 2 days of capture, but the internal organs were too decomposed for analysis. No painted carcasses were reported by the Sea Turtle Stranding and Salvage Network. The remaining 36 turtles were tagged and released alive. Three turtles were captured off Louisiana, 10 off the west coast of Florida, 23 off the east coast of Florida, 3 off Georgia and 1 off South Carolina. No turtles were captured off Texas.

Catch rates of turtles in standard shrimp nets varied by region and season (Table 14). Four turtles captured in try nets were not used in the calculations for this Table. Fishing effort was standardized to 100 ft headrope per tow using the formula,

$$E' = E \times 100/H$$

where E = tow time in minutes
H = sum of the headrope length in feet for a tow
E' = standardized effort

Turtle mean CPUE (R) and its 95% confidence interval (C.I.) were calculated according to Snedecor and Cochran (1967) for ratio estimates using the formula,

$$R = \Sigma T / \Sigma E'$$

where T = turtle captures
E' = standardized effort

$$\text{estimated standard error of } R = \frac{1}{x}\sqrt{\frac{\Sigma(T-RE')^2}{n(n-1)}}$$

where n = sample size
x = mean of the standardized effort

The total annual capture of turtles by the commercial shrimp fleet was projected using the 5 million hours of fishing effort in the Gulf of Mexico and 0.5 million hours of fishing effort in the Atlantic for calendar year 1988 (Table 14). Effort values from 1988 were used for our projection since fishing effort in the Gulf of Mexico has been increasing at a rate of approximately 7.5% per year since 1980; Atlantic effort, although fluctuating as compared to the Gulf of Mexico, was also high in 1988. Based on 5 million hours of fishing effort, we estimated 14,112 turtle captures by the commercial fleet in the offshore Gulf of Mexico during 1988, and 14,986 turtle captures in 0.5 million hours of fishing effort in the Atlantic. Mortality rates for turtles captured in trawls cannot be accurately estimated because survival of released turtles us unknown.

Biological Yield Models

Ricker-type (Ricker, 1975) yield models for each of the three major shrimp species show the same basic curve shape (Nance et al. 1989). The curves shown in Fig. 12 are very flat around the region where yield estimates are plotted for current fishing mortality rates (F-multiples = 1.0). Thus, with current fishing patterns and current fishing mortality rates, little increase or decrease in yield is predicted with the minor reductions in F that would be expected due to small losses of shrimp by TEDs.

A decrease of 10% in F (loss of 10% of shrimp catch with a TED-net compared to a standard net) would result in an estimated 0% change in overall-yield in both the brown and white shrimp fisheries and a 2% decrease in the yield for the pink shrimp fishery. A decrease of 20% in F would result in an estimated decrease in overall yield of 1% in the white shrimp fishery, 2% in the brown shrimp fishery and 5% in the pink shrimp fishery. These estimated decreases in overall yield for each fishery are so small that year to year variability in recruitment and growth rates would tend to overshadow any losses from TED usage.

DISCUSSION

This report is based on data collected by NMFS observers during cooperative cruises with the shrimp industry participants. Since this was a voluntary program, area and time of sampling could not be controlled, resulting in great imbalances in the data set by region, season and TED type. During the first year of the study we focused our efforts on primarily one design and obtained relatively good coverage for Georgia TEDs with and without funnels.

Along the Atlantic coast we had adequate samples from Georgia TEDs without funnels, but virtually no samples from Georgia TEDs with funnels. There was high sampling effort during the summer and winter months, but almost no sampling during spring and fall. Conversely, in the Gulf of Mexico most sampling was with Georgia TEDs with funnels and very little sampling with Georgia TEDs without funnels. We collected sufficient data off the Texas coast during the peak shrimping seasons of summer and fall, and off the southwest Florida coast during peak shrimping seasons of winter and spring. However, off the Louisiana coast, we obtained minimal information during summer and fall, the time of peak shrimp abundance in that area.

In general, the results are functions of the type of TED predominating in an area and the specific times and places fished. Catch rates for TEDs along the Atlantic coast are characteristic of the Georgia TED without funnel, the primary gear tested in that area, and catch rates in the Gulf of Mexico reflect Georgia TEDs with funnels. Thus, there is confounding among area (Atlantic, Gulf of Mexico), TED-type and season.

Gear Performance

Overall, there was a high degree of similarity in shrimp catchability between TED-equipped and standard nets. When there were problems with both the TED-equipped and standard nets, TED-equipped nets lost proportionally more shrimp and finfish than standard nets. Standard nets, even with problems, retained more of the shrimp and finfish catch than the TED-equipped nets. Any debris that clogged or choked the net would undoubtedly affect the performance of an operating TED, either keeping the door open continually or jamming the door so that both shrimp and finfish could easily escape. Standard nets did not have an escape door through which shrimp and fish could exit. When problems were encountered, catch rates were reduced by approximately 1.4 lbs/hr for shrimp, and by around 16.7 lbs/hr for finfish. However, the overall percentage of problems was low both with and without TEDs, with good gear performance about 90% for all nets.

Although there are areas within the Gulf and Atlantic where tow problems are more frequent, for example, the rough bottom areas of Florida's Tortugas fishing grounds, our sampling was not adequate to document all these areas. Problems were more random than systematic and occurred in both standard and TED-equipped nets. Overall, there was a high degree of similarity in gear performance between these types of nets. Further, we found that the average catch per unit effort (CPUE) of observer boats was similar to the CPUE of the commercial fleet for that given area and time. Thus, our sampling efforts did represent commercial shrimping at that time and for that given area. Therefore, the results of this program are meaningful in terms of evaluation of TEDs under commercial conditions.

<u>Relationships Between Standard and TED-Equipped Nets</u>

There was a very strong correlation (r ranged from 0.87 to 0.95) between the lbs of shrimp/hr caught in a standard net and the lbs of shrimp/hr caught in a TED-equipped net for all areas, seasons and vessels. This indicates a strong linear relationship between catch rates of shrimp of both net types.

We also examined the relationship between the catch of shrimp and fish. Although the r^2 values were low, the correlations between the fish and shrimp catch rates were highly significant. Because of the impact of fish on the shrimp catch, we used the multivariate paired t-tests analysis as the "best" statistical means for simultaneously comparing catch rates between TED and standard nets.

General Linear Model (GLM) analyses for unbalanced data were also performed. The "best" models were those in which the dependent variable was represented by the difference between the natural logarithm of shrimp catch in standard vs TED-equipped nets, or the natural logarithm of the ratio of shrimp catches in

TED-equipped vs standard nets. Because of inherent difficulties with interpretation of GLMs and the greatly imbalanced data sets, we felt that these statistical tests were inferior to those of the multivariate paired t-tests, but they provided another way of describing differences between standard and TED-equipped nets. Nevertheless, the results of the GLM indicated that more variation in the dependent variables was accounted for by region than season, and more by season than by TED type. They also show that when mean differences were significant there was a shrimp loss by TEDs, but gains in shrimp catch by TED-equipped nets were not significant.

Comparison Between Standard and TED-equipped Nets

Seasons. The differences in the CPUEs using multivariate t-tests for simultaneous evaluation of overall catch rates clearly show significant mean differences between standard and TED-equipped nets. Further, there are significant mean differences in the overall catch rates between the two TED types for both the shrimp and finfish. We have plotted these differences to show the relationship between standard and TED CPUEs by season, for shrimp and finfish (Figs. 13 and 14). In all cases the shrimp and finfish CPUEs for the TED were significantly less than CPUEs for the standard net. However, the fact that the shrimp CPUE mean differences were not very large is of practical importance. CPUEs varied between seasons just as abundance of shrimp on the fishery grounds also varies between seasons. The differences in shrimp CPUE between net type varied seasonally and ranged from a low of 0.1 lbs/hr in winter to a high 1.4 lbs/hr during summer.

The standard net caught, on the average, larger amounts of finfish than the TED-equipped net for the same season (Fig. 14). As an example, during the spring months the standard net caught 89.3 lbs/hr fish, whereas the TED-equipped net caught only 85.6 lbs/hr for a difference of approximately 3.7 lbs/hr; during the summer months the standard net caught 69.3 lbs/hr and the TED-equipped net 53.9 lbs/hr or a difference of approximately 15.4 lbs/hr of fishing. This reduction in the finfish catch was statistically significant during the summer months but not significant during any other season.

<u>Areas.</u> We also examined the difference in catch rates between standard and TED-equipped nets by geographical area. Again, shrimp and finfish catch rates for TEDs were lower than catch rates for the standard net. Differences in shrimp CPUE between net types were significant in all areas except Cape Canaveral. In the Cape Canaveral area (Fig. 15) the shrimp catch rates for the standard net were 4.7 lbs/hr, whereas for the TED-equipped net it was 4.4 lbs/hr or a difference of only 0.3 lbs/hr. In other Atlantic coast areas the shrimp catch rates averaged 8.8 lbs/hr in the standard net, but only 7.2 lbs/hr in the TED-equipped net, a difference of 1.6 lbs/hr. Shrimp CPUE differences by net type in the Gulf of Mexico were much less, ranging from 0.5 lbs/hr to 0.8 lbs/hr.

Areal differences may be confounded with those from net type. Georgia TEDs without funnels predominated on vessels on the Atlantic coast whereas those with funnels dominated in the Gulf of Mexico. The effectiveness of the TED-type may influence the catch rates of shrimp. By-in-large, gear specialists have reported that the Georgia TED with funnel is more effective in retaining shrimp than the same TED without a funnel (personal communication, John Watson, NMFS, Pascagoula, MS).

Overall finfish catch rates differed significantly between TED-equipped and standard nets. Comparisons by geographical area showed significant differences for only a few areas (Fig. 16). The catch rate of finfish by area was also different for TED-equipped or standard nets. The Louisiana coast of the Gulf of Mexico had the highest finfish catch rates: 114 lbs/hr with the standard net as compared to 110.9 lbs/hr for the TED-equipped net, a difference of about 3.1 lbs/hr. Finfish catch rate differed significantly between TED-equipped and standard nets only in southwest Florida and the Atlantic coasts. The reason for this difference is unclear. The Atlantic coast catch rates were 82.6 lbs/hr for the standard net and 62.2 lbs/hr for the TED-equipped net (a difference of 20.4 lbs/hr). In southwestern Florida, rates were 46.9 lbs/hr and 40.3 lbs/hr for the standard and TED-equipped net, respectively.

Net Type. Shrimp catch rates were reviewed for the two TED types. Catch rate for the standard net was 7.2 lbs/hr versus 5.9 lbs/hr for the net equipped with a Georgia Jumper without a funnel, a difference of 1.3 lbs/hr (Fig. 17). For quad-rigged vessels, the standard net caught 6.7 lbs/hr and the Georgia TED with funnel caught 5.9 lbs/hr for a difference of 0.7 lbs/hr. Overall, there appeared to be some dissimilarity in the shrimp catch rate differences when the two TED types were compared (see above).

For twin-rigged vessels, the catch rate for the standard net was 9.9 lbs/hr versus 10.2 lbs/hr for the Georgia Jumper with a funnel, however, without the funnel the Georgia Jumper's catch rate was 5.2 lbs/hr versus 6.0 lbs/hr for the standard net (Fig. 18). A major difference was observed in the loss rate of shrimp depending on the type of TED. The Georgia Jumper with the funnel was clearly superior and showed no significant difference in shrimp loss when compared to the standard net.

Likewise, the overall difference of finfish catch rates between standard and TED-equipped nets were compared for each of the two TED types (Fig. 19). These data showed a significant reduction in fish catch for both TED types. The Georgia TED with and without a funnel reduced the finfish catch rate by 11.5 lbs/hr and 8.3 lbs/hr, respectively.

Biological Model.

Shrimp catch rates by TED-equipped nets were usually lower than those in standard nets and mean rates varied from 2% better to 15% worse for quad-rigged vessels. When the catch of shrimp in the try nets was added to the catch in the inboard net immediately behind the try net, the results indicated that the mean loss rate ranged from 3% loss to approximately 18% loss for the Georgia TED without a funnel. As previously stated, we feel that the try net adjustment is biased in favor of standard nets because 76% of all the tows with the try net were in front of the standard net and only 24% were in front of the TED-equipped net. When we compared shrimp CPUEs between standard and TED-equipped nets there was a 6% mean difference in catch rates with the try net adjustment. Although there appears to be an inherent bias within the try net adjustments, we have provided analyses both with and without try net adjustments. Whether the range in the CPUE data is +2% to -15% (e.g., without try net adjustments) or a loss of 3-18%, there is, in every case except one, a loss in shrimp catch rate. However, for twin-rigged vessels the overall mean catch in shrimp CPUE was not significantly different between TEDs and standard nets (Table 10). As discussed previously, the multivariate paired t-test analysis shows that these differences were significant overall. We have demonstrated that the shrimp loss rate is relatively small practically, ranging from 0.2 lbs/hr to 1.6 lbs/hr, depending upon the area, season, and TED type. Therefore, we have taken the opportunity to determine what this loss rate would mean to total production in the shrimp fishery. Yield curves have been generated for each of the shrimp fisheries by using models to determine total yield with a variety of different fishing pressures (Fig. 12). At present levels of fishing effort (F-multiplier = 1.0) each curve is very flat to either side (Nance et al., 1989). Thus, because of the flat-topped nature of the curve at the present level of fishing, any increases in fishing mortality rates would not increase the yield of shrimp. Likewise, a decrease in fishing mortality rates of 10 or 20% would not significantly decrease the overall production of shrimp.

We have assumed 1) that a shrimp escaping through either a TED-equipped net or a standard net will not die because of that episode (no increase in natural mortality rates), and 2) that such escaping shrimp will join the remaining population, will grow and experience the same natural mortality as the rest of the stock. Phares (1978), describing the selectivity of shrimp nets, showed a loss rate of shrimp varying by area and season, with an extensive size range of lost shrimp. Therefore, we have assumed that mortality incurred by shrimp escaping from TED-equipped nets would be no greater than that experienced from standard nets. In fact, the survival rate of shrimp escaping from TED-equipped nets might be increased because the opening in the TED-equipped net is larger than the mesh openings in the cod end of a standard net. If there were a decrease of 20% in the catch rate and this translated to a fishing mortality decrease of 20%, we would estimate a resultant decrease in overall yield of only 1% in the white shrimp fishery, 2% in the brown shrimp fishery, and approximately 5% in the pink shrimp fishery. By this we mean that there is ample fishing effort on the grounds to capture the animals for that given year-class, and that a reduction in the fishing mortality rate due to loss of shrimp by TEDs will not greatly affect the overall yield. Although this decrease may, in fact, impact a given individual fisherman on any particular tow, what he loses in that tow will still be available to him for capture by succeeding tows that day or the next and might even be accessible to him within the next couple of months.

The fishery yield could benefit overall if effort is concentrated on young small emigrating shrimp that have growth potential exceeding the reduction due to natural mortality. Thus the overall yield could be enhanced through reduction in growth overfishing (Klima et al., 1982; Nance et al., 1989; Nichols, 1982). The lowering of shrimp catch rates due to TEDs may not be viewed as all unfortunate depending on the time of year when this occurs.

Turtle Capture.

During the study, turtles were captured in all regions except the western Gulf (statistical areas 18-21), an area where we had considerable observer effort. This is not to imply that turtles are not caught by shrimp trawlers off the state of Texas. In May 1989, a commercial shrimper fishing off Freeport caught a loggerhead turtle in approximately 10 fathoms of water. Further, Henwood and Stuntz (1987) identified 16 loggerheads and 4 Kemp's ridley turtles taken by shrimpers in the western Gulf for a catch rate of 0.002 ± 0.001 (turtles/net hour) for loggerhead turtles. Whether the capture rate is at the same level today is unknown.

The data for strandings in 1986-1987 show a large number of turtles along the Texas coast (Fig. 20). The proportion of those strandings due to shrimping is unknown at present. However, the turtle stranding rate decreased during June when the offshore waters were closed to all shrimping except to daytime shrimping in 0-4 fathoms. Most strandings occurred in March, April, May and again in July and August and the remaining fall months. Up to 51 of these strandings in 1986 were possibly related to removal of oil platforms using explosives, as documented by Klima et al. (1988). Since 1987, the removal of oil platforms has been controlled by the Minerals Management Service and NMFS through a Section 7 Consultation under the Endangered Species Act and an intensive observer program. There have been no documented turtle mortalities resulting from platform removals since that date.

At-sea capture of turtles was highest along the Atlantic coast and especially high off Cape Canaveral and Mayport, FL. Also, a high capture rate was found off southwest Florida on the Sanibel fishing grounds. Three sea turtles were caught off the panhandle of Florida during the spring of 1989.

In spring, loggerheads concentrate along the east coast of Florida from Brevard to Palm Beach counties (Thompson, 1988). In the fall, they migrate to southeast U.S. waters and the Gulf of Mexico. In the Gulf of Mexico, loggerheads appear to concentrate along the central-west coast of Florida. Aerial surveys during the early to mid 1980s showed the ratio of loggerhead turtle sightings for the northwestern Gulf to northeastern Gulf to be about 1 to 25. Loggerheads also nest along the Florida west coast, but only sporadically elsewhere along the Gulf of Mexico coast.

Fishing effort in the Gulf of Mexico has been increasing at a rate of approximately 7.5% per year since 1980 (Fig. 21); in the Atlantic, fishing fluctuates greatly from year to year depending upon the abundance of shrimp with no apparent trend since 1982 (Fig. 22). Nevertheless, the fishing power in the Atlantic and the Gulf of Mexico is at extremely high levels and turtles that are found on shrimping grounds are certainly vulnerable to capture by shrimp trawlers as calculated by Henwood and Stuntz (1987). Those authors estimated 12,947 turtle captures based on 4.3 million hours of fishing effort in the Gulf of Mexico, and 33,871 turtle captures in 0.7 million hours of fishing effort in the combined inshore and offshore of the Atlantic. Our estimate of 14,112 turtles captured in the Gulf of Mexico in 5 million hours accompanies a 16% increase in fishing effort but only a 8% increase in captures. We estimated 14,986 turtle captures in the Atlantic based on 0.5 million hours of offshore effort. Henwood[1] attributes 67% of the Atlantic effort to offshore fishing. Adjustment of their earlier results to reflect only offshore effort reduces the capture estimate to 22,694 turtles in approximately 0.47 million hours. Our estimate of 14,986 turtle captures represents a decrease of 34% despite a 6% increase in shrimping effort in the offshore Atlantic.

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[1]Personal Communication (1990), Dr. Terry Henwood, NOAA, SEFC, NMFS, 9450 Koger Blvd., St. Petersburg, FL 33702.

Our data document turtle capture rates by season and area. The data also clearly indicate that TEDs do significantly reduce the capture of turtles by shrimp trawlers in commercial operations.

SUMMARY

This report represents partial fulfillment of OMB and House Appropriations Committee requirements with respect to TEDs and their economic impact on the shrimp fishery. Information on the performance of standard and TED-equipped nets was collected by National Marine Fisheries Service (NMFS) observers placed on commercial shrimp vessels in the Atlantic and Gulf of Mexico. Vessel captains permitted NMFS observers to collect catch rate and net performance information from simultaneously towed standard and TED-equipped nets. Sampling areas, times and length of tows were controlled by the captain. From March 1988 through July 1989, a total of 48 trips encompassing 4,159 fishing hours were conducted resulting in a total of 776 paired tows. All of the data collected were used in the analyses with the exception of cases when the cod end became untied, nets were badly torn or non-TED related problems affected the catch.

Due to the voluntary nature of the program, we were unable to control areas and times of sampling, so there were great imbalances in the data set. Along the Atlantic coast, we obtained adequate samples with Georgia TEDs without funnels but virtually no samples with Georgia TEDs with funnels. There was a dearth of sampling with Georgia TEDs without funnels along the Gulf of Mexico; there was satisfactory sampling with Georgia TEDs with funnels in most areas but only during peak fishing seasons.

Standard and TED-equipped nets appeared to operate similarly with respect to types and frequency of problem tows. When problems with the fishing gear occurred, the TED-equipped nets lost more shrimp and finfish than standard nets.

The catch rates of the observer vessels participating in this program were not significantly different from the catch rates for the commercial fleets fishing in the same area during the same time frame. Therefore, we feel that the results of this observer program are representative and meaningful in terms of the evaluation of two types of Georgia TEDs under commercial conditions.

This voluntary program precluded choosing the location of the try net. The captain made that decision and in 76% of the tows, the captain located the try net in front of the standard net. To compensate for the location of the try net we either omitted its catch or added its catch to the trailing net. This adjustment increased the catch in standard nets by 6% while having no apparent effect in the catch of the TED-equipped net.

Multivariate paired t-tests were judged the most appropriate means for comparing differences in the CPUEs between standard and TED-equipped nets. In general, for quad-rigged vessels, there were significant mean differences in the paired catch rates between the standard and TED-equipped nets for both shrimp and finfish. In all cases, the overall mean difference between CPUEs of standard and TED-equipped nets were positive, indicating that standard nets caught more shrimp and finfish than TED-equipped nets. The mean differences in the seasonal shrimp catch rates were less than 0.9 lbs/hr without including try net data and 1.4 lbs/hr with try net catch added to the trailing net. Shrimp CPUE ranged seasonally from a gain of 0.1 lbs/hr to a loss of 1.4 lbs/hr. CPUE varied seasonally and only during the winter months were there no significant differences in the overall shrimp catch rates between standard and TED-equipped nets. During all other seasons differences were significant.

The overall finfish CPUEs were 74.0 and 64.5 lbs per hour for standard and TED nets respectively or a mean difference of 9.4 lbs per hour.

Differences in shrimp and finfish catch rates between standard and TED-equipped nets varied by geographic area, and in all cases catch rates were less in TED-equipped than in standard nets. Differences in the shrimp CPUE were significant in all geographical areas with the exception of Cape Canaveral.

Significant differences were noted between the shrimp catch rates of the two TED types. When the Georgia TED without a funnel was compared with the standard net, the catch rate for the standard net was 7.2 lbs/hr and 5.9 lbs/hr for the TED-equipped net, or a difference of 1.3 lbs/hr. The Georgia TED with the funnel caught 5.9 lbs/hr compared to of 6.7 lbs/hr for the standard net, or a difference of 0.7 lbs/hr. Differences between TED-types may be confounded with areal and seasonal factors.

The overall finfish catch rates were also significantly reduced by both the Georgia TED with and without a funnel as compared to a standard net. The mean differences were 8.3 and 11.5 pounds per hour respectively for the Georgia TED with and without a funnel.

For twin rigged-vessels, the overall shrimp CPUE with TED-equipped nets ranged from 2% better than the standard net to 18% worse than the standard nets with a try net adjustment. No significant difference was observed in the overall catch rates between TED and standard nets for twin-rigged vessels. However, there was a significant difference in the catch rates between the Georgia TED without a funnel and the standard net, but no difference with the Georgia TED with a funnel and the standard net.

Yield was modelled to determine what impact various levels of shrimp loss would have on overall shrimp production. Overall, a decrease of 10% in fishing mortality rate resulted in no detectable change in the overall yield for both brown and white shrimp fisheries and a 2% decrease in the yield for the pink shrimp fishery. A decrease of 20% in F decreased the overall yield 1% in the white shrimp fishery, 2% in the brown shrimp fishery, and approximately 5% in the pink shrimp fishery.

A total of 40 turtles were caught in the observer program, of which 27 were caught along the Atlantic coast and 13 were caught in the Gulf of Mexico. Nine of the 40 came aboard unconscious, and 36 were released alive. The estimated total capture of turtles using 1988 fishing effort is 14,112 for the Gulf of Mexico and 14,986 turtles for the Atlantic Ocean.

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LIST OF TEXT TABLES

LIST OF TEXT FIGURES

Table 1. Frequency of operation codes for standard net, Georgia TED without funnel, and Georgia TED with a Funnel.

A. By Group

Operation Code	Standard Net Freq.	%	Georgia TED w/o funnel Freq.	%	Georgia TED w/funnel Freq.	%
Group 1[a]	128	6.3	54	8.9	102	10.2
Group 2[b]	1904	93.7	553	91.1	900	89.8

[a] Group 1 = operation codes A, B, C, E, F, N, O, S, T plus multiple codes containing one of these letters. These codes reflect gear-related problems which may or may not be attributed to TEDs.

[b] Group 2 = operation codes G, I, J, K, L, M, P, Q, U, Z, plus multiple codes containing only these letters. These codes reflect tows with no gear-related problems attributable to TEDs.

B. For Codes F and O.

Operation Code	Standard Net Freq.	%	Georgia TED w/o funnel Freq.	%	Georgia TED w/funnel Freq.	%
F	21	1.0	31	5.1	13	1.3
O	14	0.7	1	0.2	27	2.7

Table 2. CPUE (lbs/hr/4 nets) comparisons of observed catch rates of standard nets with commercial catch rates; by season and statistical area. Data are from 39 trips on twin and quad-rigged observer vessels in the Gulf of Mexico and interviews of the commercial shrimp fleet.

Season	Statistical Area	Data Type	Number of trips	CPUE $\pm$ Standard Error (lbs/hr)
Summer-Fall	9-12	Standard	3	22.8 $\pm$ 0.42
Summer-Fall	9-12	Commercial	283	14.6 $\pm$ 0.03
Summer-Fall	13-17	Standard	6	14.7 $\pm$ 0.20
Summer-Fall	13-17	Commercial	1538	18.6 $\pm$ 0.02
Summer-Fall	18-21	Standard	14	23.4 $\pm$ 0.15
Summer-Fall	18-21	Commercial	3804	18.8 $\pm$ 0.01
Winter-Spring	1-8	Standard	6	16.7 $\pm$ 0.27
Winter-Spring	1-8	Commercial	1221	15.3 $\pm$ 0.02
Winter-Spring	9-12	Standard	3	8.9 $\pm$ 0.14
Winter-Spring	9-12	Commercial	162	8.4 $\pm$ 0.05
Winter-Spring	13-17	Standard	4	10.7 $\pm$ 0.15
Winter-Spring	13-17	Commercial	739	12.1 $\pm$ 0.03
Winter-Spring	18-21	Standard	3	6.5 $\pm$ 0.65
Winter-Spring	18-21	Commercial	1601	10.4 $\pm$ 0.02

Table 3. Results of multivariate paired t-test for quad-rigged vessels; all data without try nets. Comparisons between CPUE (lbs/hr) of standard and TED-equipped nets; by tow.

		P Values			Difference (std-TED) between Mean CPUEs (lbs/hr)			
	N TOWS	Simultaneous	CPUE (lbs/hr) shrimp	CPUE (lbs/hr) fish	shrimp	shrimp %	fish	fish %
Overall	706	<0.01	<0.01	<0.01	.6	(+10)	9.4	(+13)
TED type[a]								
4	256	<0.01	<0.01	<0.01	.9	(+14)	11.4	(+16)
9	450	<0.01	<0.01	.02	.5	(+8)	8.3	(+11)
Months								
Dec-Feb	142	.30	.57	.87	-.1	(-2)	1.3	(+2)
Mar-May	148	<0.01	<0.01	.70	.7	(+15)	3.7	(+4)
Jun-Aug	340	<0.01	<0.01	<0.01	.9	(+11)	15.4	(+22)
Sep-Nov	76	<0.01	<0.01	.28	.7	(+11)	9.2	(+10)
Areas								
1-8	106	<0.01	<0.01	.01	.7	(+13)	6.7	(+14)
9-12	88	.20	.22	.44	.4	(+5)	4.0	(+6)
13-17	154	<0.01	<0.01	.84	.4	(+8)	3.1	(+3)
18-21	112	.04	.05	.31	.4	(+5)	5.1	(+15)
28	60	.05	.64	.06	.2	(+4)	12.2	(+16)
30-32	186	<0.01	<0.01	<0.01	1.3	(+15)	20.4	(+25)
Day/Night								
Day	290	<0.01	<0.01	<0.01	.8	(+12)	10.5	(+12)
Night	338	<0.01	<0.01	.02	.6	(+9)	8.9	(+15)
Both	78	.06	.10	.41	.5	(+8)	7.8	(+8)

[a] TED type 4 has no funnel; TED type 9 has a funnel.

Table 4. Results of multivariate paired t-test for quad-rigged vessels; all data with try nets included. Comparisons between CPUE (lbs/hr) of standard net and TED-equipped nets; by tow.

	N TOWS	P Values: Simultaneous	P Values: CPUE (lbs/hr) shrimp	P Values: CPUE (lbs/hr) fish	Difference (std-TED) between Mean CPUEs (lbs/hr): shrimp	shrimp %	fish	fish %
Overall	706	<0.01	<0.01	<0.01	0.9	(+13)	9.4	(+13)
TED type[a]								
4	256	<0.01	<0.01	<0.01	1.3	(+18)	11.5	(+16)
9	450	<0.01	<0.01	.02	0.7	(+11)	8.3	(+11)
Months								
Dec-Feb	142	.33	.34	.87	0.1	(+3)	1.4	(+2)
Mar-May	148	<0.01	<0.01	.70	0.7	(+14)	3.7	(+4)
Jun-Aug	340	<0.01	<0.01	<0.01	1.4	(+16)	15.4	(+22)
Sep-Nov	76	<0.01	<0.01	.28	0.7	(+10)	9.2	(+10)
Areas								
1-8	106	<0.01	<0.01	.01	0.8	(+14)	6.7	(+14)
9-12	88	<0.01	<0.01	.45	0.6	(+8)	4.0	(+6)
13-17	154	<0.01	<0.01	.84	0.5	(+11)	3.1	(+3)
18-21	112	<0.01	<0.01	.31	1.0	(+13)	5.2	(+15)
28	60	.05	.28	.06	0.3	(+6)	12.3	(+16)
30-32	186	<0.01	<0.01	<0.01	1.6	(+18)	20.4	(+25)
Day/Night								
Day	290	<0.01	<0.01	<0.01	1.0	(+14)	10.5	(+12)
Night	338	<0.01	<0.01	.02	0.9	(+13)	8.9	(+15)
Both	78	.01	.01	.41	0.6	(+11)	7.8	(+8)

[a] TED type 4 has no funnel; TED type 9 has a funnel.

Table 5. Number of tows in which try net was in front of standard or TED-equipped nets; Georgia TED types combined.

	Number	%
Standard	664	76
TED	213	24
Total	877	

Table 6. Comparison of mean CPUE (lbs/hr) with and without try net for standard and TED-equipped nets; Georgia TED types combined.

	Mean CPUE (lbs/hr)		
	Without trynet	With trynet	% diff
Standard net	6.5	6.9	6
TED net	5.9	5.9	0

Table 7. Comparision of mean CPUE (lbs/hr) and their differences for standard and TED-equipped nets (Georgia TED types combined) with and without trawling problems.

	Mean CPUE (lbs/hr)					
	Shrimp			**Fish**		
	Standard net	TED	diff	Standard net	TED	diff
Without try net						
No problem[1] tows	6.2	5.8	0.4±.19	70.3	63.1	7.3±5.5
Problem[2] tows	7.6	6.2	1.4±.54	86.1	69.4	16.7±10.5
With try net						
No problem tows	6.5	5.8	0.7±.2			
Problem tows	8.1	6.3	1.8±.5			

1 No problem tows: operational codes A, E, F, O, S, B, C, Z ,L (refer to Appendix)

2 Problem tows: all other operational codes (refer to Appendix)

Table 8. Results of multivariate paired t-test for quad-rigged vessels; all data without try nets. Comparisons between CPUE (lbs/hr) of standard and TED-equipped nets; by trip.

	N TRIPS	P Values: Simultaneous	P Values: CPUE (lbs/hr) shrimp	P Values: CPUE (lbs/hr) fish	Difference (std-TED) between Mean CPUEs (lbs/hr): shrimp	shrimp %	fish	fish %
Overall	41	<0.01	<0.01	<0.01	.6	(+9)	7.3	(+13)
TED type[a]								
4	17	<0.01	.02	<0.01	1.0	(+16)	12.0	(+20)
9	24	.13	.14	.33	.4	(+5)	3.9	(+8)
Months								
Dec-Feb	10	.28	.93	.32	.0	(+1)	7.9	(+16)
Mar-May	6	.30	.31	.90	.9	(+14)	0.7	(+2)
Jun-Aug	23	<0.01	.01	.01	.8	(+10)	8.6	(+16)
Sep-Nov	2							
Areas								
1-8	6	.01	.30	.18	.9	(+14)	3.9	(+11)
9-12	5	.99	.99	.99	.0	(+1)	0.5	(+1)
13-17	4	.21	.75	.99	.5	(+10)	0.1	(0)
18-21	10	.73	.74	.78	.2	(+3)	1.8	(+7)
28	4	.22	.66	.29	.2	(+6)	18.6	(+31)
30-32	12	<0.01	.03	.01	1.3	(+16)	15.0	(+21)
Day/Night								
Day	2							
Night	10	.32	.33	.60	.6	(+7)	2.7	(+10)
Both	29	<0.01	.01	.01	.6	(+10)	7.6	(+12)

[a] TED type 4 has no funnel; TED type 9 has a funnel.

Table 9. Results of multivariate paired t-test for quad-rigged vessels; all data with try nets. Comparisons between CPUE (lbs/hr) of standard net and TED-equipped nets; by trip.

	N TOWS	P Values: Simultaneous	P Values: CPUE (LBS/HR) shrimp	P Values: CPUE (LBS/HR) fish	Difference (std-TED) between Mean CPUEs (lbs/hr): shrimp	shrimp %	fish	fish %
Overall	41	<0.01	<0.01	<0.01	.9	(+13)	7.3	(+13)
TED type[a]								
4	17	<0.01	.01	<0.01	1.2	(+19)	12.0	(+20)
9	24	<0.01	<0.01	.33	0.7	(+10)	3.9	(+8)
Months								
Dec-Feb	10	.19	.33	.32	0.2	(+6)	7.9	(+16)
Mar-May	6	.12	.21	.90	1.0	(+14)	0.7	(+2)
Jun-Aug	23	<0.01	<0.01	.01	1.3	(+15)	8.6	(+16)
Sep-Nov	2							
Areas								
1-8	6	.02	.30	.18	0.8	(+12)	3.9	(+11)
9-12	5	.73	.76	.99	0.3	(+5)	0.5	(+1)
13-17	4	.06	.37	.99	0.7	(+14)	-0.1	(0)
18-21	10	.05	.05	.78	0.9	(+12)	1.8	(+7)
28	4	.19	.62	.29	0.3	(+8)	18.6	(+31)
30-32	12	<0.01	.01	.01	1.5	(+19)	15.0	(+21)
Day/Night								
Day	2							
Night	10	.03	.03	.60	1.4	(+14)	2.7	(+9)
Both	29	<0.01	<0.01	.01	0.8	(+13)	7.6	(+12)

[a] TED type 4 has no funnel; TED type 9 has a funnel.

Table 10. Results of multivariate paired t-test for twin-rigged vessels; all data with try nets. Comparisons between CPUE (lbs/hr) of standard and TED type nets; by tow.

	N TOWS	P Values: Simultaneous	P Values: CPUE (LBS/HR) shrimp	P Values: CPUE (LBS/HR) fish	Difference (std-TED) between Mean CPUEs (lbs/hr): shrimp	shrimp %	fish	fish %
Overall	70	.92	.94	.99	0.2	(+2)	0.2	(+1)
TED type[a]								
4	28	<.01	<.01	.80	0.8	(+13)	-0.8	(-7)
9	42	.91	.96	.93	-0.2	(-2)	0.9	(+5)
Months								
Dec-Feb	5	.18	.24	.97	1.4	(+18)	-0.3	(-3)
Sep-Nov	65	.97	.99	.99	0.1	(+1)	0.3	(+2)
Areas								
18-21	70	.92	.94	.99	0.2	(+2)	0.2	(+1)
Day/Night								
Day	60	.95	.96	.99	0.2	(+2)	0.2	(+1)
Night	6	.35	.37	.99	0.3	(+8)	0.3	(+1)
Both	4	.97	.98	.99	0.2	(+2)	0.2	(+1)

[a] TED type 4 has no funnel; TED type 9 has a funnel.

Table 11. Results of General Linear Model (GLM) analyses of paired observations from TED-equipped and standard trawls with TED type (T), Region (R) and Season (Q) as classification variables and with selected continuous variables as covariates (see Appendix II text for description of symbols used for dependent and continuous variables).

A. Data paired by tow (706 observations, quad-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$ $\ln(H)$, $\ln(D)$, V	all 2-factor and 3-factor	0.044	0.331	0.44	2.07
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.043	0.295	0.50	2.84
$\ln(S_S)-\ln(S_T)$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.041	0.407	0.18	1.94
$\ln(S_{Sadj})-\ln(S_{Tadj})$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.040	0.376	0.22	2.57
$\ln(S_S)-\ln(S_T)$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.043	0.372	0.29	1.88
$\ln(S_{Sadj})-\ln(S_{Tadj})$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.041	0.345	0.36	2.49

Table 11. (cont).

B. Data paired by trip (41 observations, quad-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	all 2-factor and 3-factor	0.018	0.555	0.82	0.52
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.017	0.471	0.18	-0.45
$\ln(S_S)-\ln(S_T)$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.015	0.757	0.94	1.06
$\ln(S_{Sadj})-\ln(S_{Tadj})$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.014	0.717	0.35	0.97
$\ln(S_S)-\ln(S_T)$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.015	0.696	0.72	1.53
$\ln(S_{Sadj})-\ln(S_{Tadj})$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.011	0.717	0.11	-0.07

Table 11 (cont).

C. Data paired by tow (64 observations, twin-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$ $\ln(H)$, $\ln(D)$, V	"	0.042	0.599	-2.36	8.46
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.027	0.650	-2.15	7.77

D. Data paired by trip (7 observations, twin-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.046	0.345	-0.35	-0.19
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.042	0.162	-0.85	0.39

[a] Mean square residual.
[b] The mean of the residuals was zero in all GLM models shown in this table.

Table 12. Least squares means (LSMs) of dependent variables for various TED types, Regions and Seasons (Q) in General Linear Model (GLM) analyses of paired observations for TED-equipped and standard trawls (see Appendix II text for description of symbols used for dependent variables).

A. Data paired by tow (706 observations, quad-rigged trawlers)

Dependent Variables	TED type (T): Georgia jumper	TED type (T): Georgia jumper, with funnel	Region (R), Statistical subarea groupings: 18-21	13-17	9-12	1-8	>21	Season (Q), Month groupings: Dec-Feb	Mar-May	June-Aug	Sept-Nov
$\ln(S_S)-\ln(S_T)$	0.09ns[a]	0.16	0.18ns	0.24	0.16	0.02ns	0.01ns	0.03ns	0.18ns	0.11	0.11ns
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.14	0.18	0.32	0.22	0.12ns	-0.03ns	0.08ns	0.11	0.09ns	0.16	0.13ns

B. Data paired by trip (41 observations, quad-rigged trawlers)

Dependent Variables	TED type (T): Georgia jumper	TED type (T): Georgia jumper, with funnel	Region (R), Statistical subarea groupings: 18-21	13-17	9-12	1-8	>21	Season (Q), Month groupings: Dec-Feb	Mar-May	June-Aug	Sept-Nov
$\ln(S_S)-\ln(S_T)$	0.09	0.11	0.11	0.57	-0.07ns	-0.07ns	0.03ns	0.03ns	0.08ns	0.14	NE[b]
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.14	0.15	0.13	0.44	-0.34ns	-0.12ns	0.06ns	0.03ns	-0.05ns	0.19	NE

Table 12 (cont).

C. Data paired by tow (64 observations, twin-rigged trawlers)

	TED type (T)		Region (R) Statistical subarea groupings					Season (O) Month groupings			
Dependent Variables	Georgia jumper	Georgia jumper, with funnel	18-21	13-17	9-12	1-8	>21	Dec-Feb	Mar-May	June-Aug	Sept-Nov
$\ln(S_S)-\ln(S_T)$	0.11ns	0.21ns									
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.24	0.22ns									

D. Data paired by trip (7 observations, twin-rigged trawlers)

	TED type (T)		Region (R) Statistical subarea groupings					Season (O) Month groupings			
Dependent Variables	Georgia jumper	Georgia jumper, with funnel	18-21	13-17	9-12	1-8	>21	Dec-Feb	Mar-May	June-Aug	Sept-Nov
$\ln(S_S)-\ln(S_T)$	0.11ns	0.04ns									
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.15ns	-0.06ns									

[a] ns indicates that the LSM was not significantly different from zero at $P \leq 0.05$; otherwise the LSM was significantly different from zero.

[b] NE indicates that the LSM was not estimable because of data imbalance (insufficient sample size).

Table 13. Turtle captures by area, net type and species.

	Area					
	TX	LA	W. FL	E. FL	GA	SC
Net Type						
Standard Net	0	3	8	21	2	1
TED-equipped net	0	0	1	0	0	0
Try net	0	0	1	2	1	0
Totals	0	3	10	23	3	1

	Area					
	TX	LA	W. FL	E. FL	GA	SC
Species						
Loggerhead	0	2	6	20	3	1
Kemp's ridley	0	1	3	2	0	0
Hawksbill	0	0	1	1	0	0
Totals	0	3	10	23	3	1

Table 14. Standard net data: observer effort, turtle captures, CPUE (turtles/hr), commercial shrimping effort, estimated captures of sea turtles in the Gulf of Mexico and the southern North Atlantic by season for 1988.

Area	Season	Num Tows	Standardized Head rope Effort(hrs)	Captured Turtles	Estimated CPUE ± 95% confidence bound (turtles/net hour)	Annual Shrimping Effort (net hours)	Estimated Turtle Catch ± 95% confidence bound
Atlantic	Winter	108	226	15			
	Spring	0					
	Summer	227	568	9			
	Fall	4	8	0			
Atlantic combined		339	803	24	0.0299±0.0112	501,192	14,986±5613
Gulf of Mexico:							
Stats 1-7 (eastern)	Winter	18	76	3			
	Spring	113	571	3			
	Summer	0					
	Fall	0					
	Combined	131	647	6	0.0093±0.0086	507,031	4,715±4,360
Stats 8-17 (central)	Winter	77	677	0			
	Spring	73	349	3			
	Summer	93	421	1			
	Fall	65	463	1			
	Combined	308	1911	5	0.0026±0.0023	2,910,788	7,568±6,694
Stats 18-21 (western)	Winter	10	92	0			
	Spring	2	12	0			
	Summer	103	574	0			
	Fall	100	648	0			
	Combined	215	1326	0		1,622,034	
Gulf Combined		654	3886	11	0.0028±0.0018	5,039,854	14,112±9,072

Table 15. TED net data: observer effort, turtle captures, CPUE (turtles/hr), commercial shrimping effort, estimated captures of sea turtles in the Gulf of Mexico and the southern North Atlantic by season for 1988.

Area	Season	Num Tows	Standardized Head rope Effort(hrs)	Captured Turtles	Estimated CPUE + 95% confidence bound (turtles/net hour)	Annual Shrimping Effort (net hours)	Estimated Turtle Catch ± 95% confidence bound
Atlantic	Winter	108	215	0			
	Spring	0					
	Summer	227	561	0			
	Fall	4	8	0			
Atlantic combined		339	784	0		501,192	
Gulf of Mexico: Stats 1-7 (eastern)	Winter	18	73	1			
	Spring	113	555	0			
	Summer	0					
	Fall	0					
	Combined	131	628	1	0.0016±0.0032	507,031	811±1,622
Stats 8-17 (central)	Winter	77	650	0			
	Spring	73	349	0			
	Summer	93	526	0			
	Fall	65	458	0			
	Combined	308	1984	0		2,910,788	
Stats 18-21 (western)	Winter	10	82	0			
	Spring	2	12	0			
	Summer	103	640	0			
	Fall	100	642	0			
	Combined	215	1378	0		1,622,034	
Gulf Combined		654	3991	1	0.0003±0.0005	5,039,854	1,512±2,520

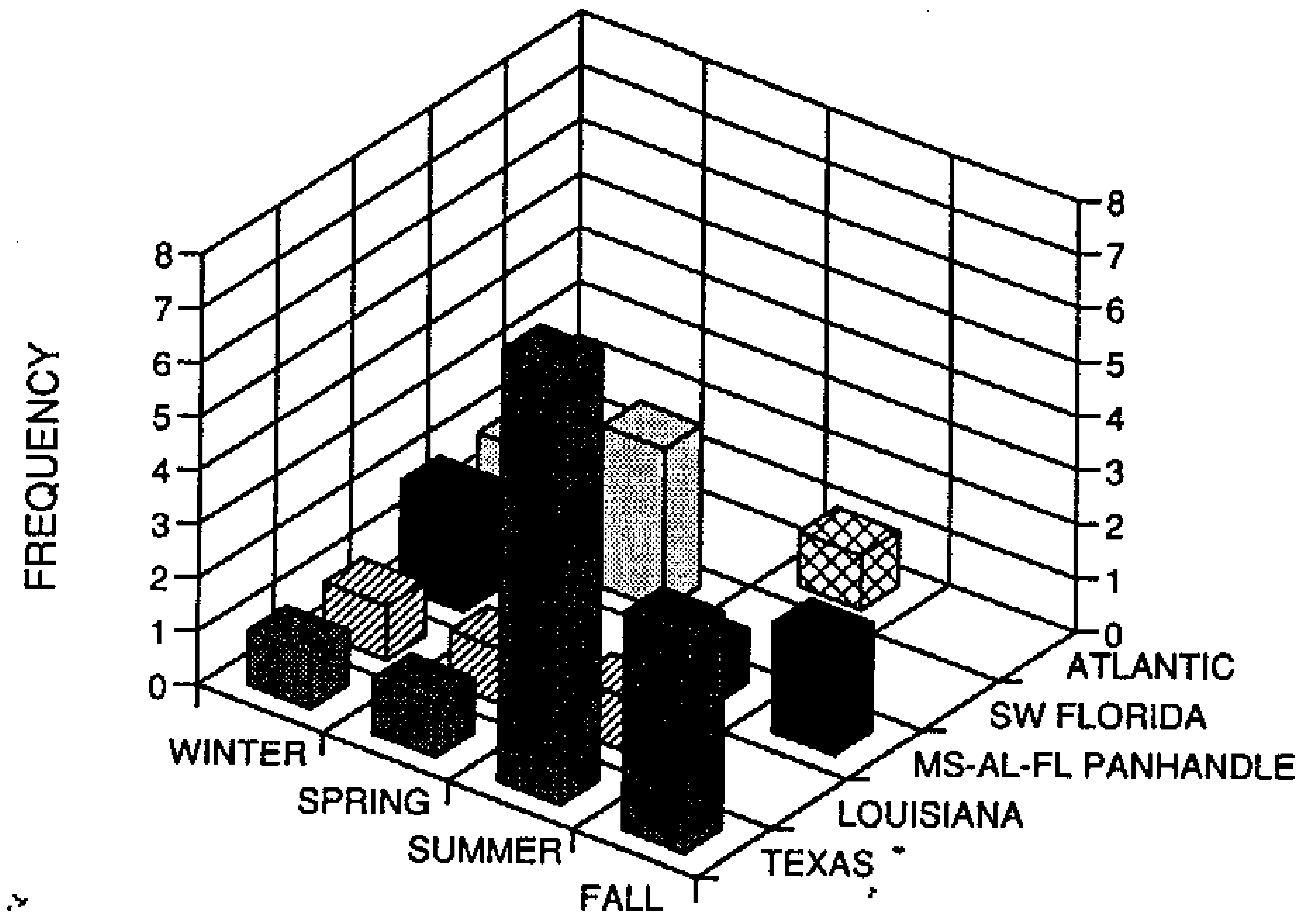


Figure 1. Frequency of trips using Georgia TEDs (with funnels) by season and area (N = 28).

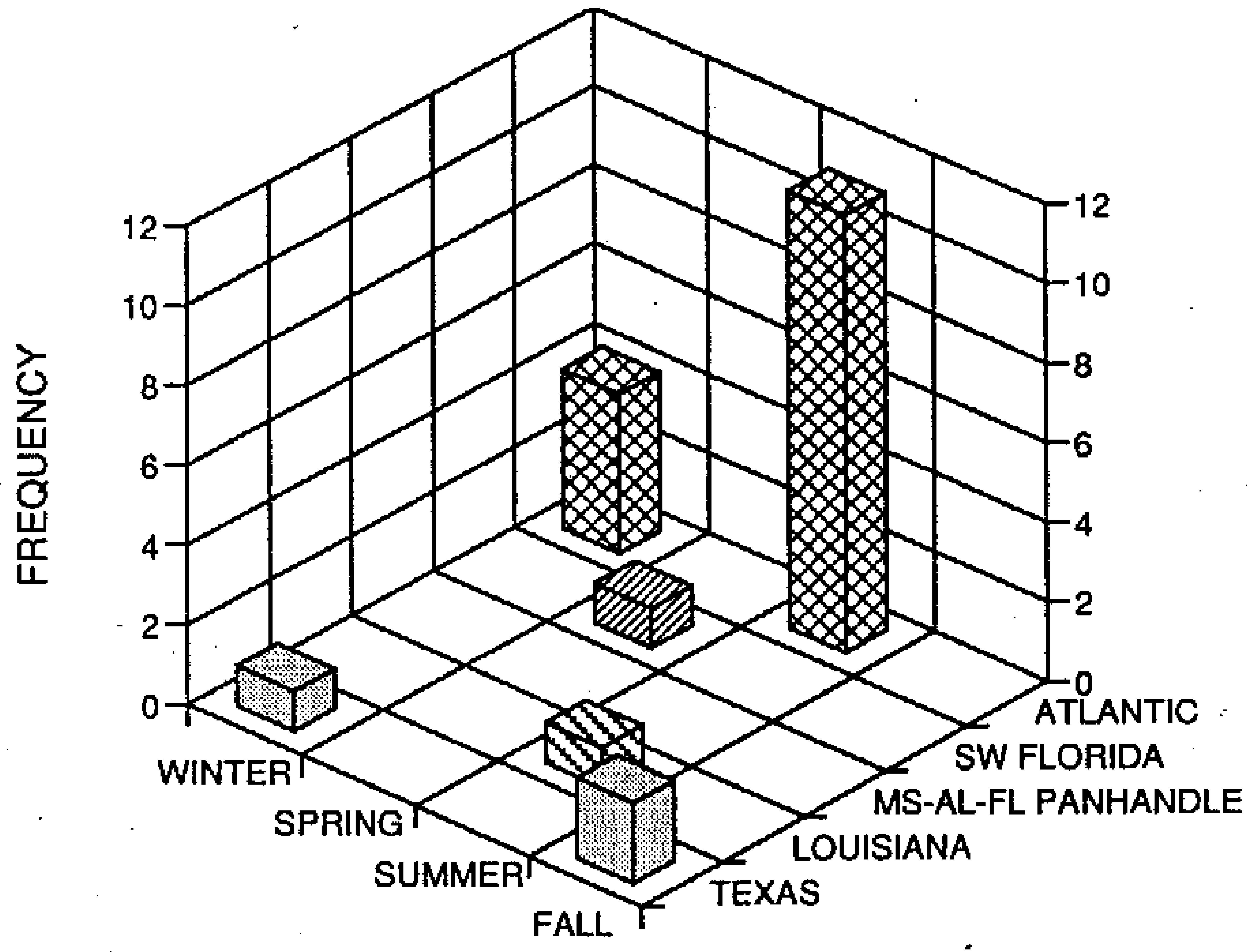


Figure 2. Frequency of trips using Georgia TEDs (without funnels) by season and and area (N = 20).

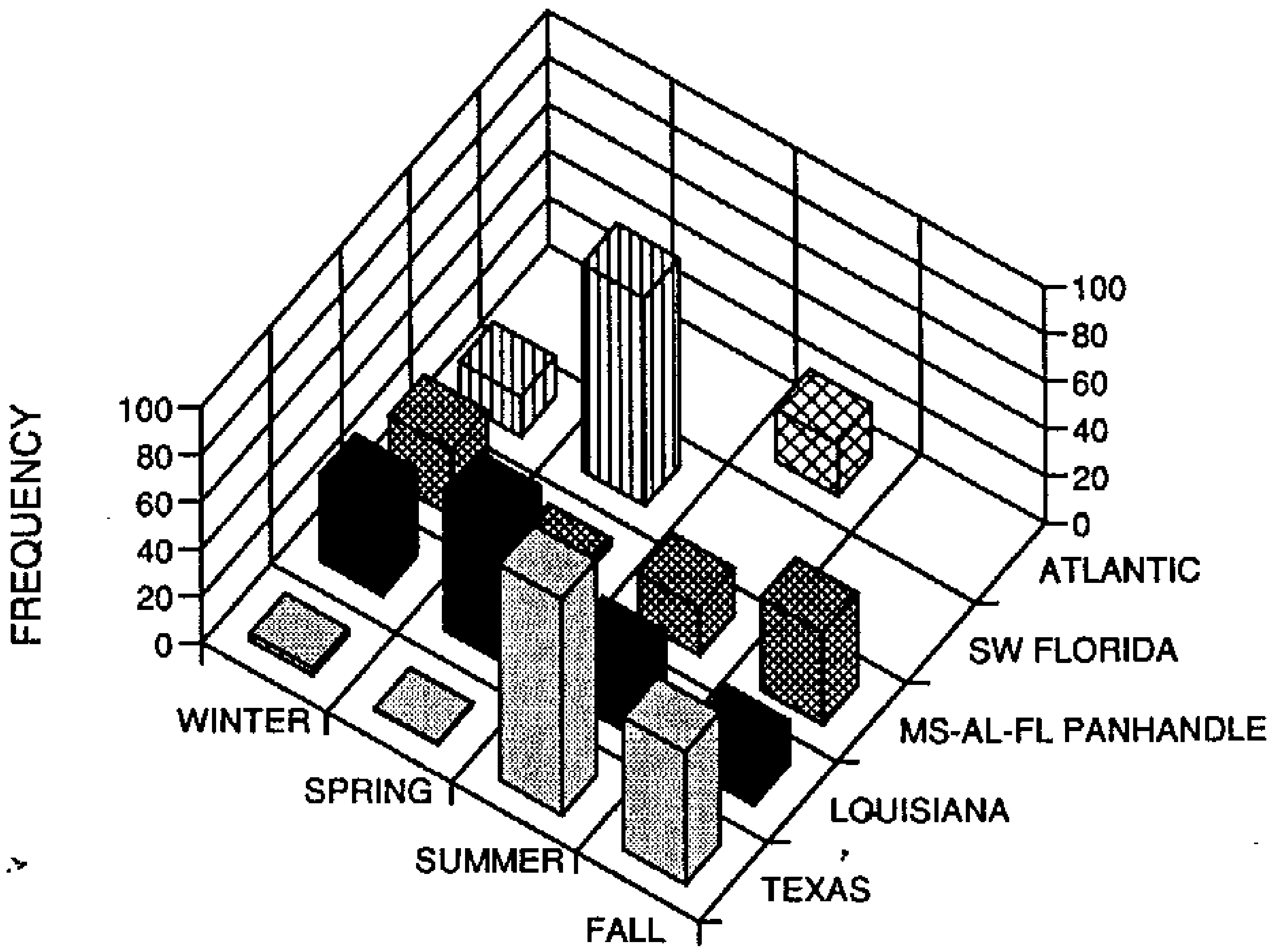


Figure 3. Frequency of standard and Georgia TED (with funnel) tow data pairs by season and area (N = 510).

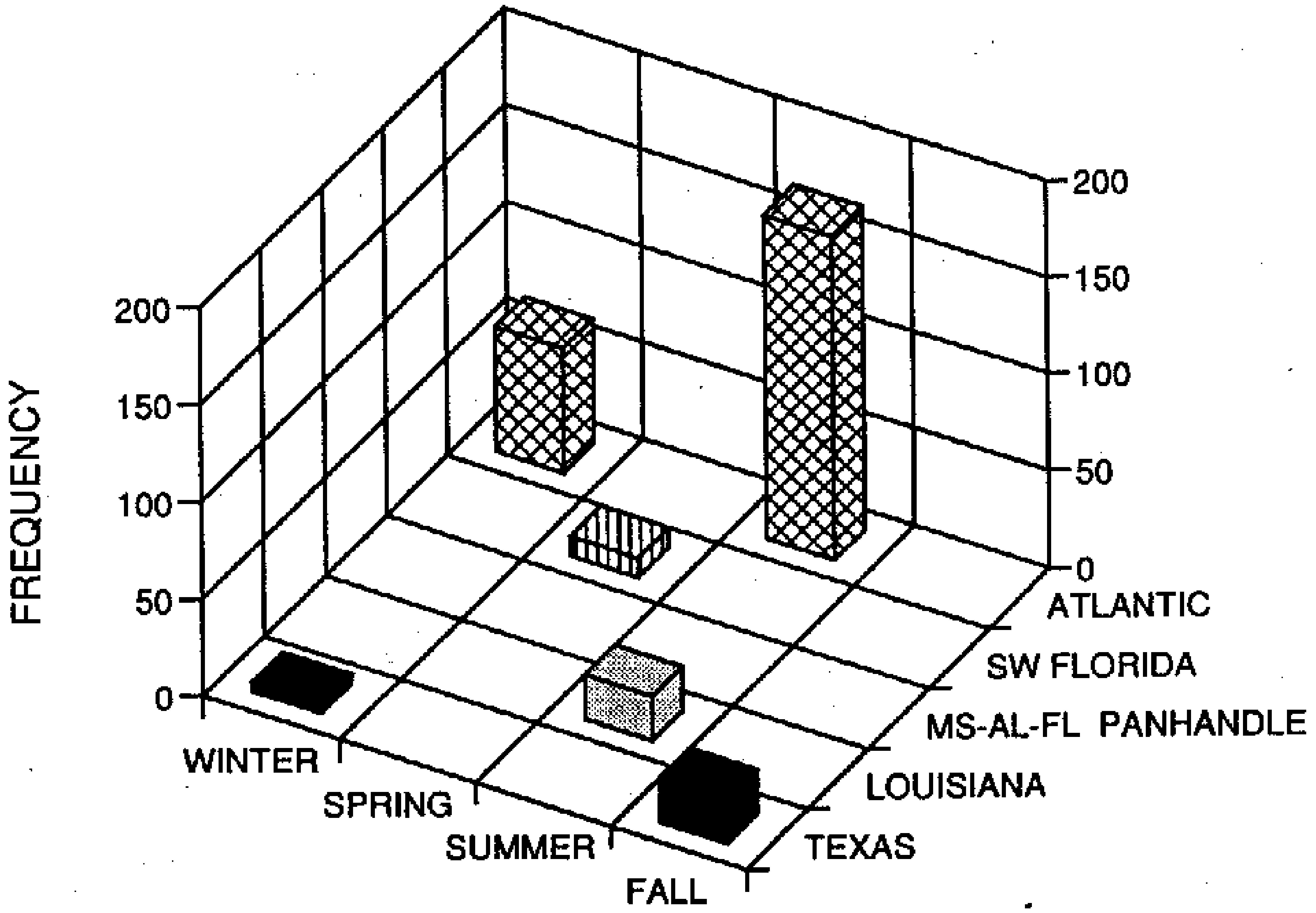


Figure 4. Frequency of standard and Georgia TED (without funnel) tow data pairs by season and area (N = 292).

FIGURE 5. TED SHRIMP CATCH VS STANDARD SHRIMP CATCH, NOT ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED
N = 770

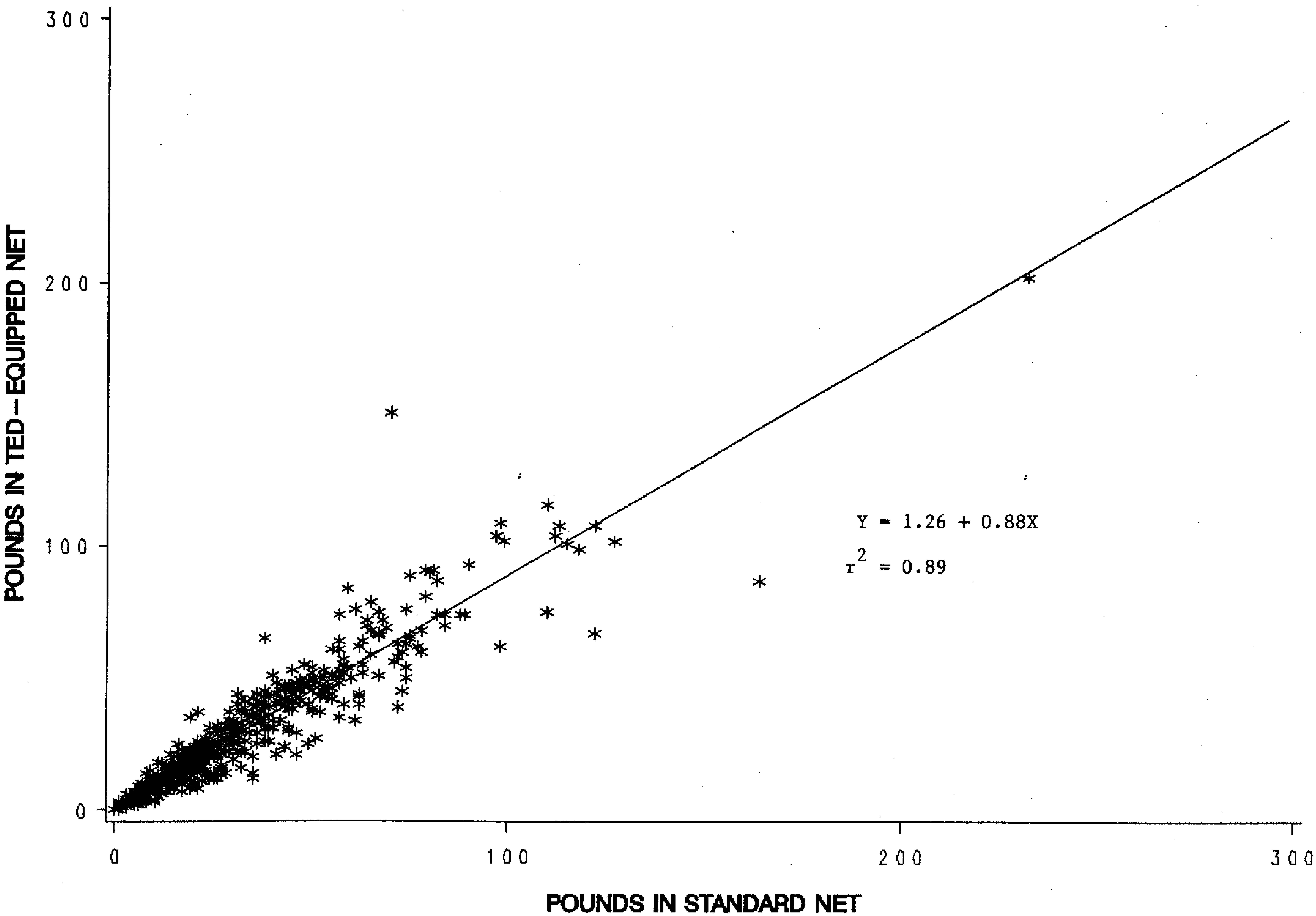


FIGURE 6. TED SHRIMP CATCH VS STANDARD SHRIMP CATCH, ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED

N = 770

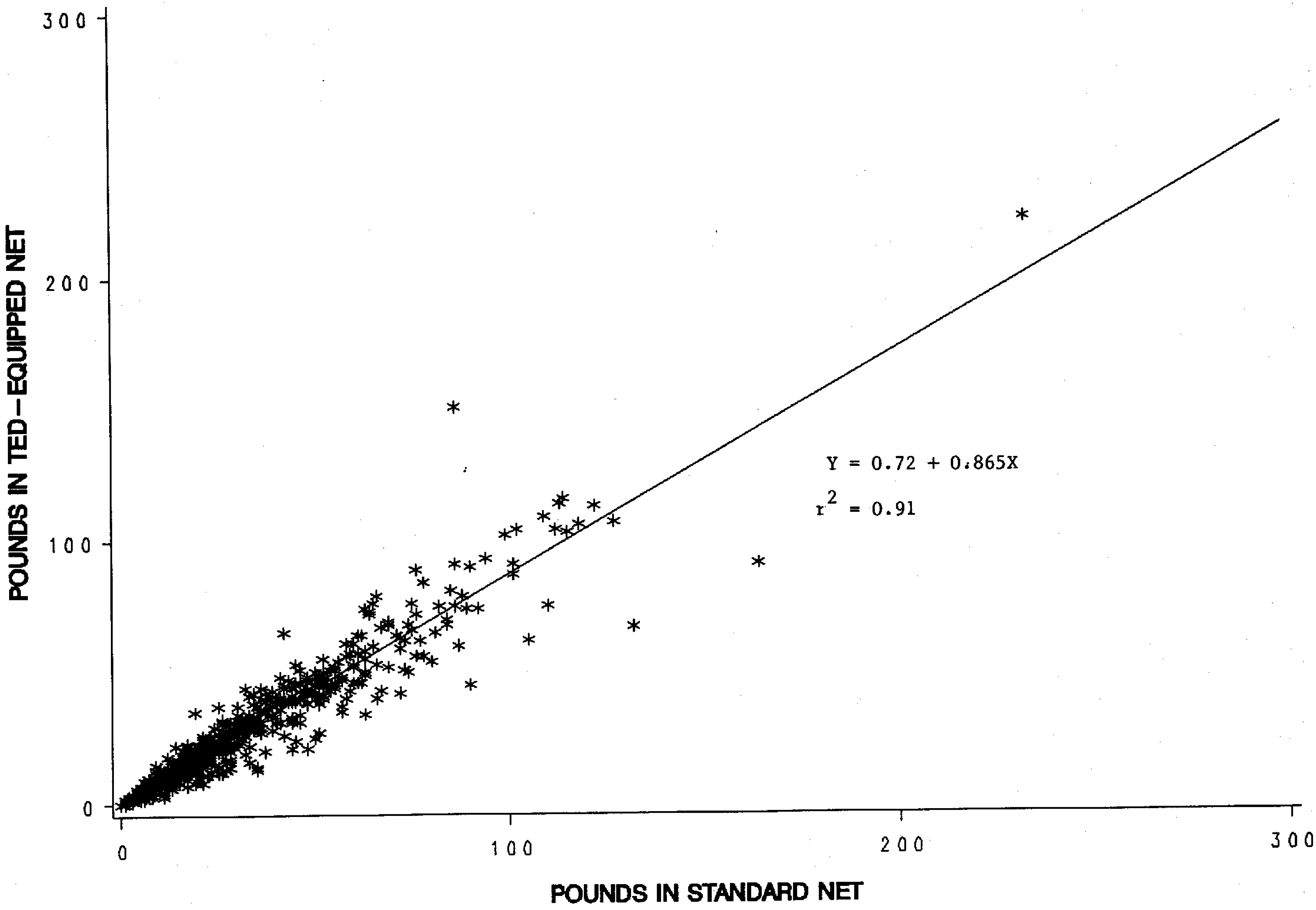


FIGURE 7. TED SHRIMP CPUE (LBS/HR) VS STANDARD SHRIMP CPUE (LBS/HR), NOT ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED
N = 770

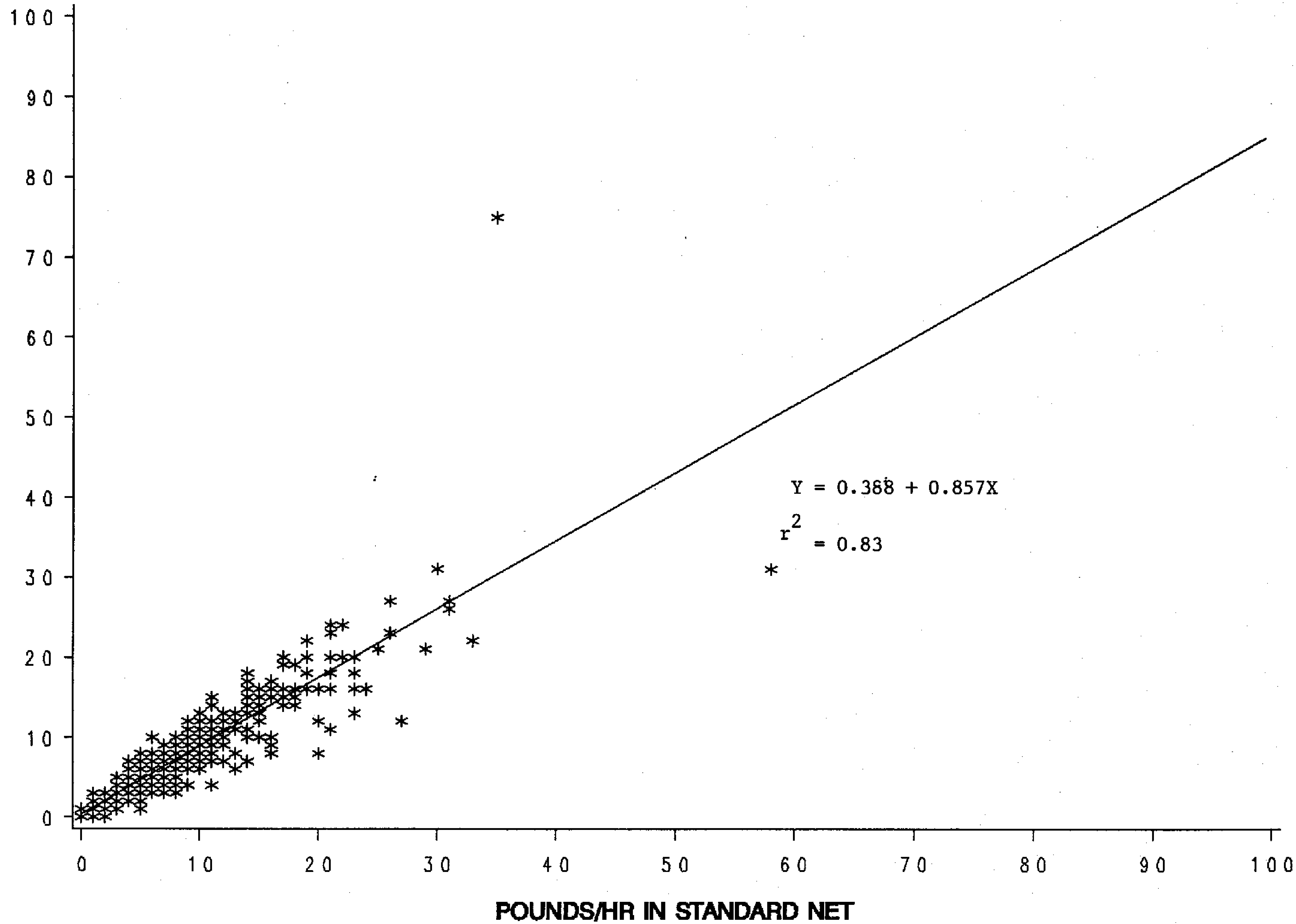


FIGURE 8. TED SHRIMP CPUE (LBS/HR) VS STANDARD SHRIMP CPUE (LBS/HR), ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED
N = 770

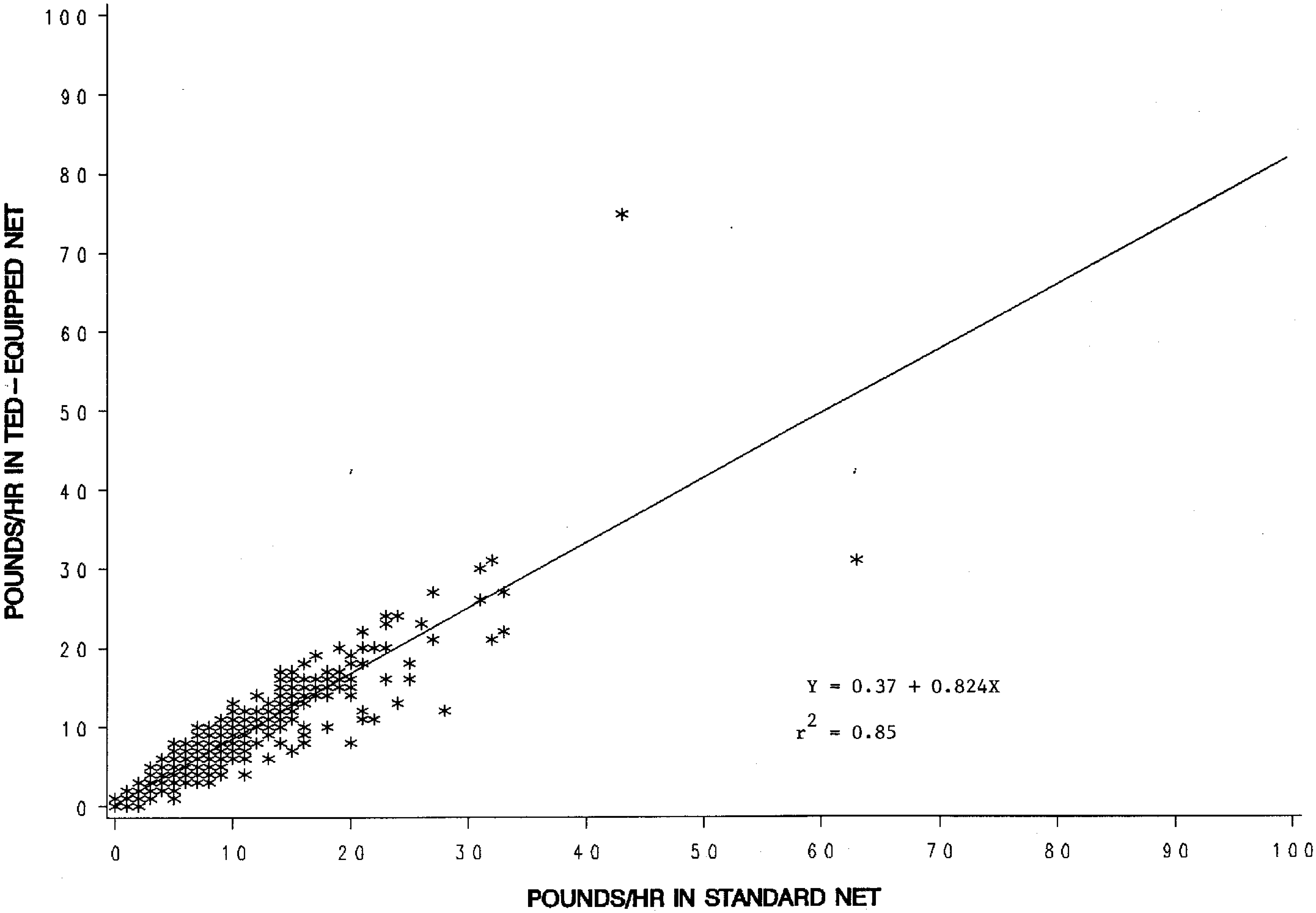


FIGURE 9. TED SHRIMP CATCH VS TED FISH CATCH
NOT ADJUSTED FOR TRY NET CATCH
ALL AREAS/VESSELS COMBINED
N = 770

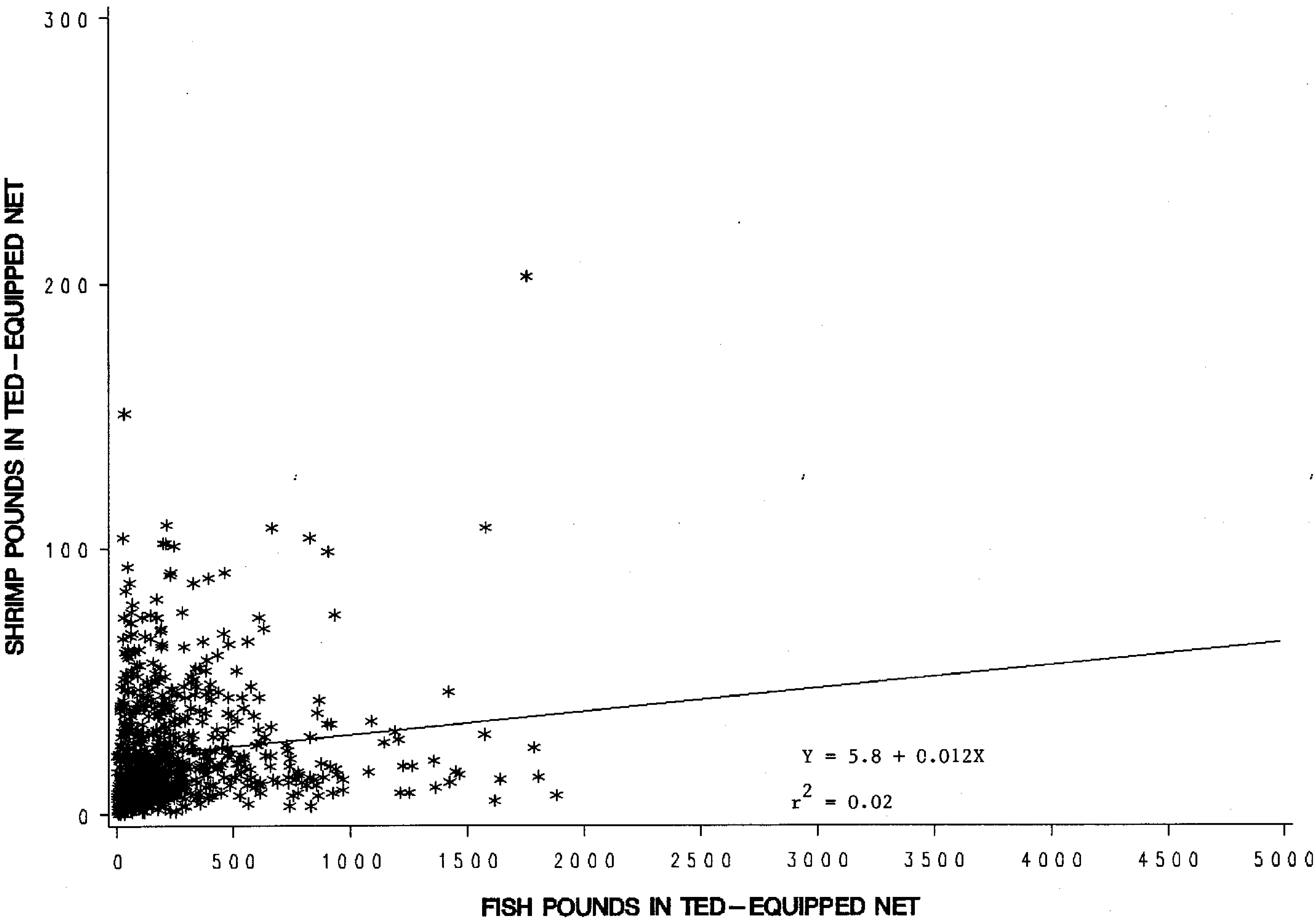


FIGURE 10. TED SHRIMP CATCH VS TED FISH CATCH
ADJUSTED FOR TRY NET CATCH
ALL AREAS/VESSELS COMBINED
N = 770

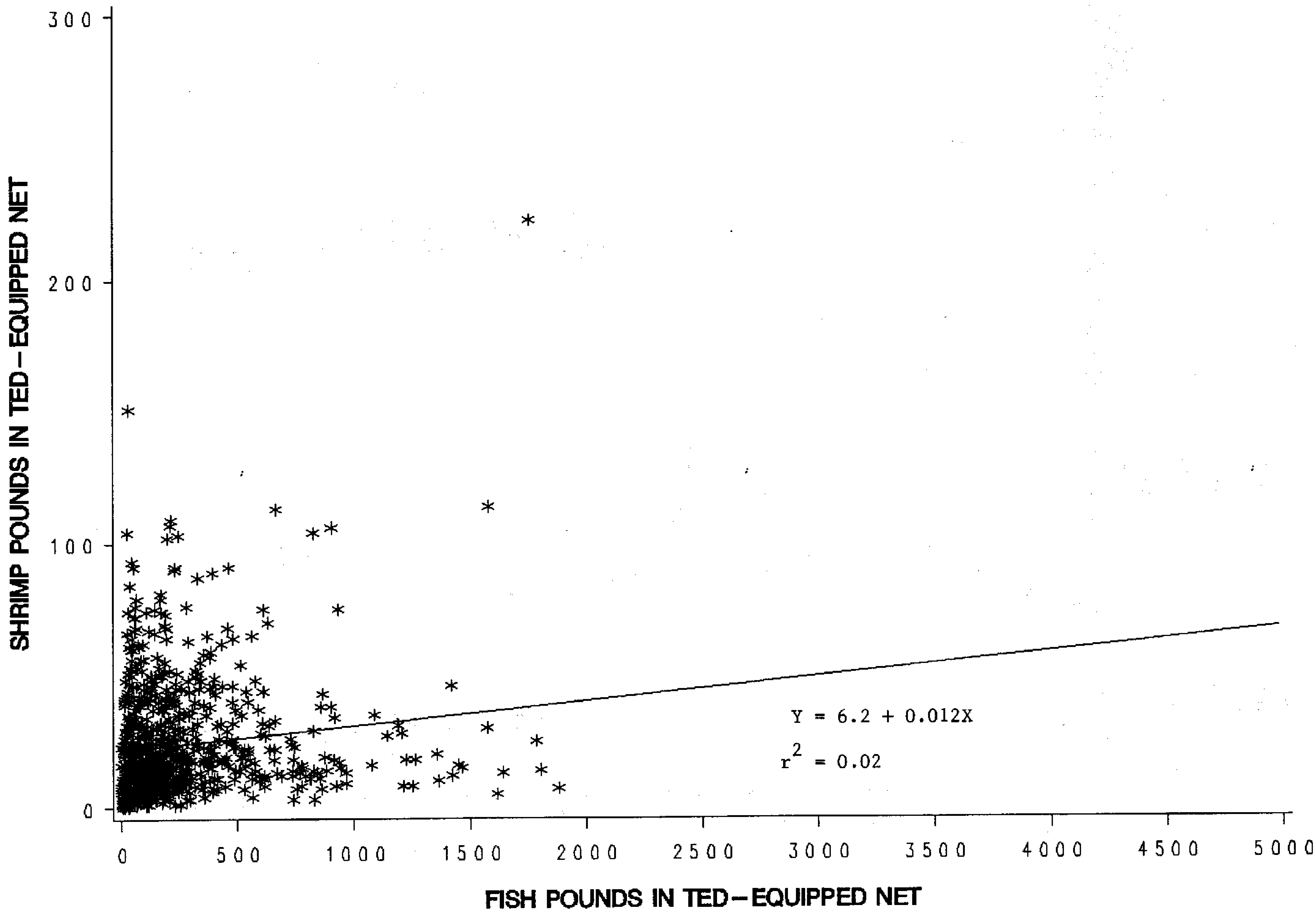
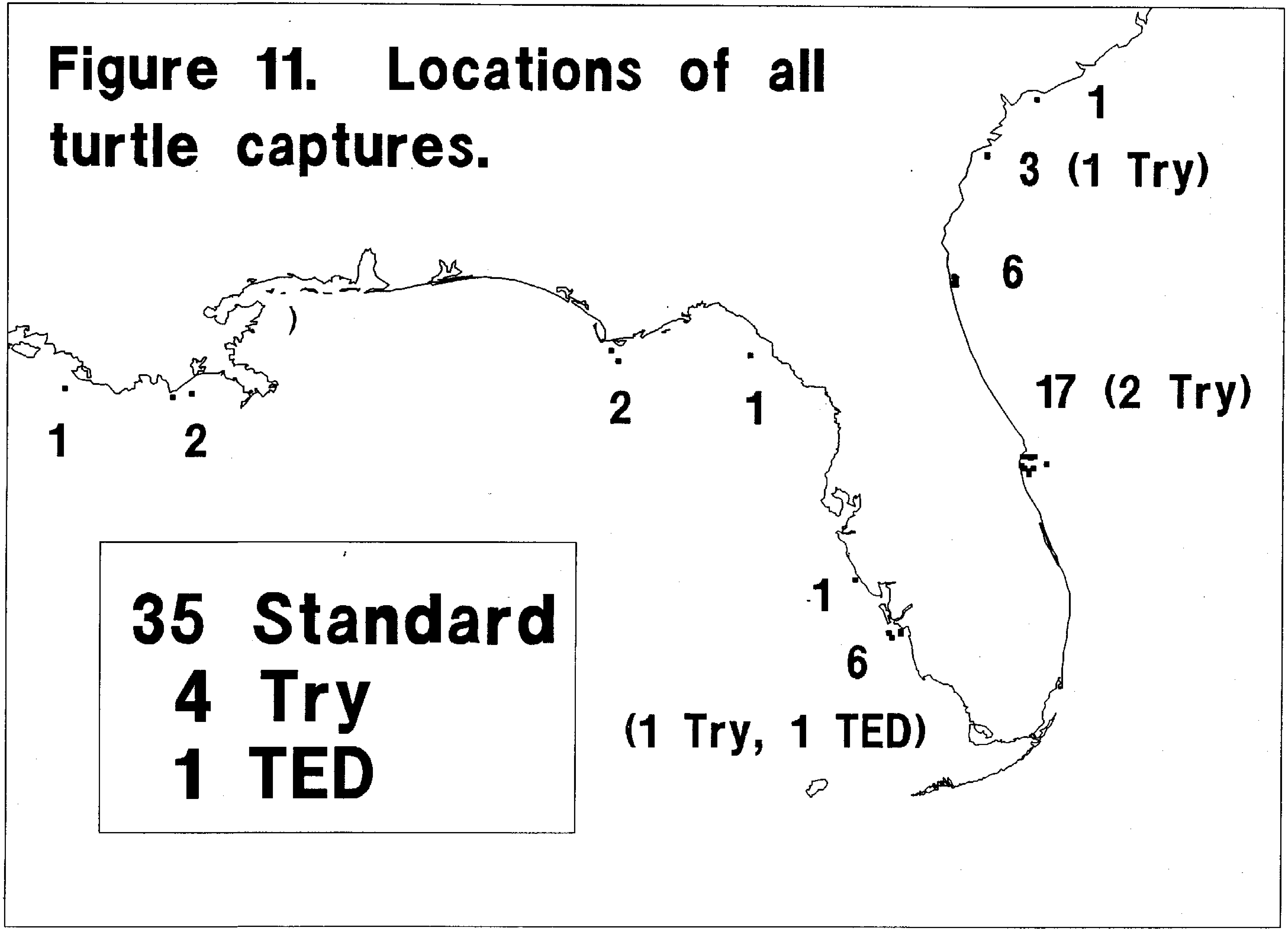


Figure 11. Locations of all turtle captures.



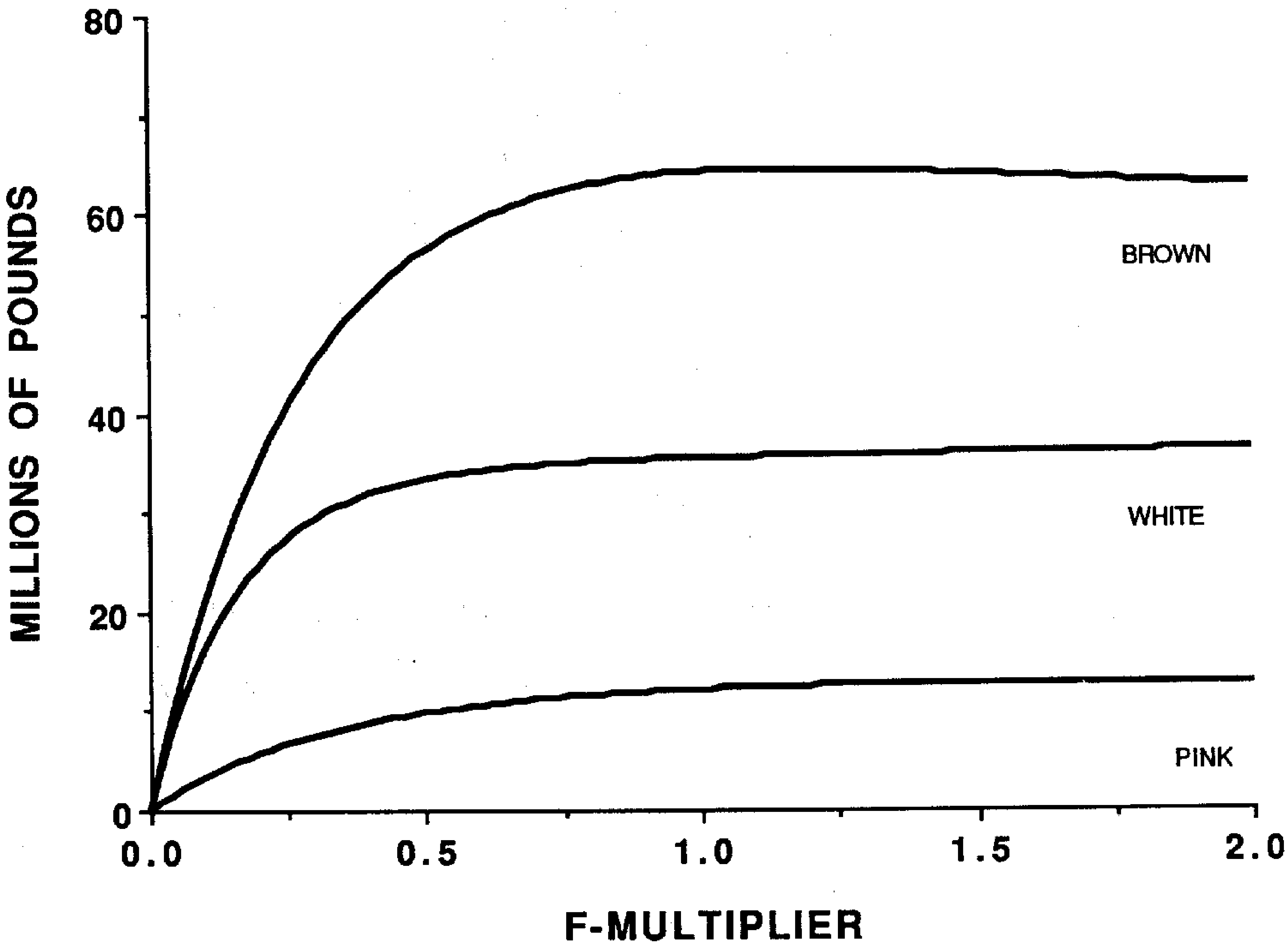


Figure 12. Yield curves.

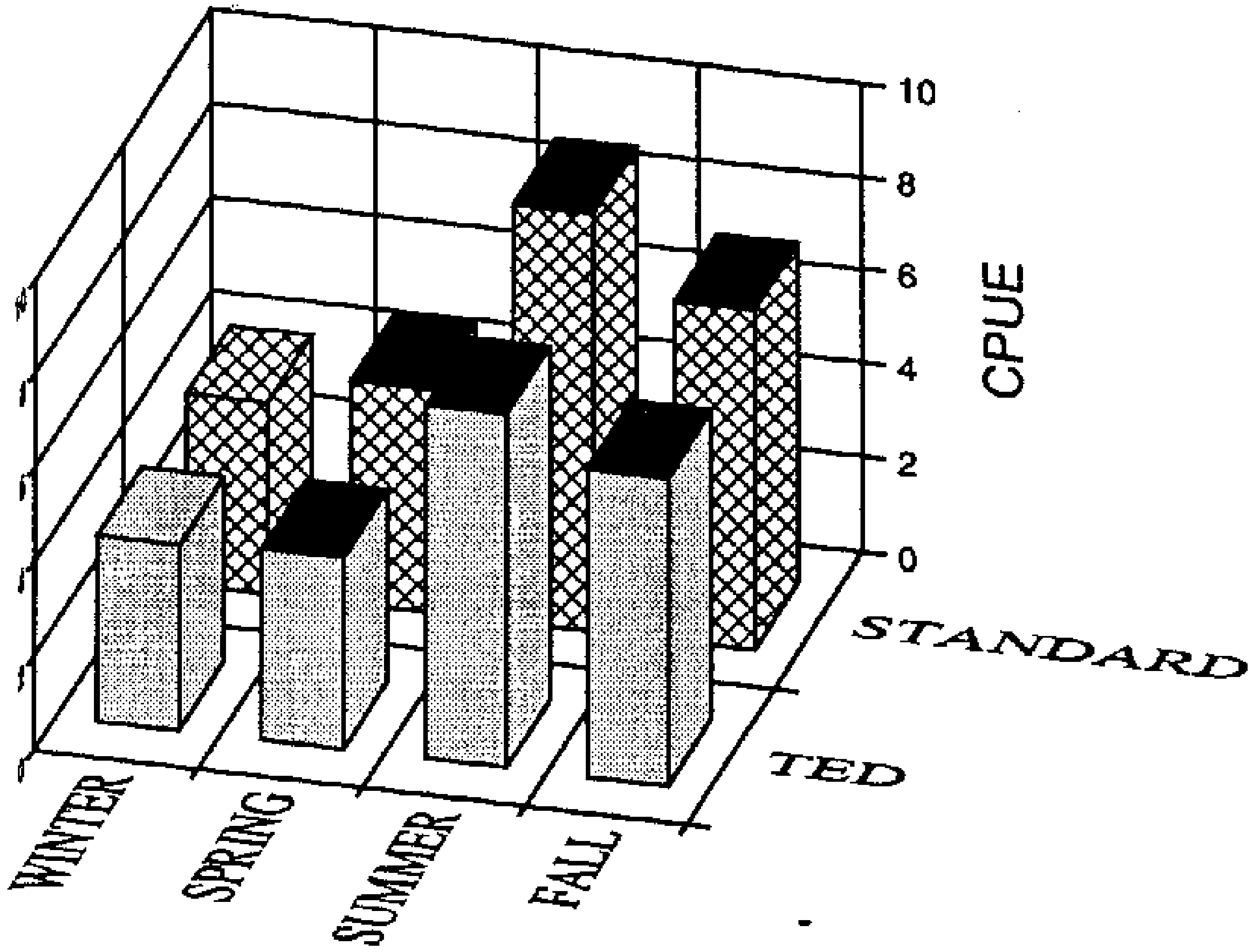


Figure 13. Differences in CPUE (lbs/hr) of shrimp between standard and TED-equipped nets, by season. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706). Quad-rigged vessels only.

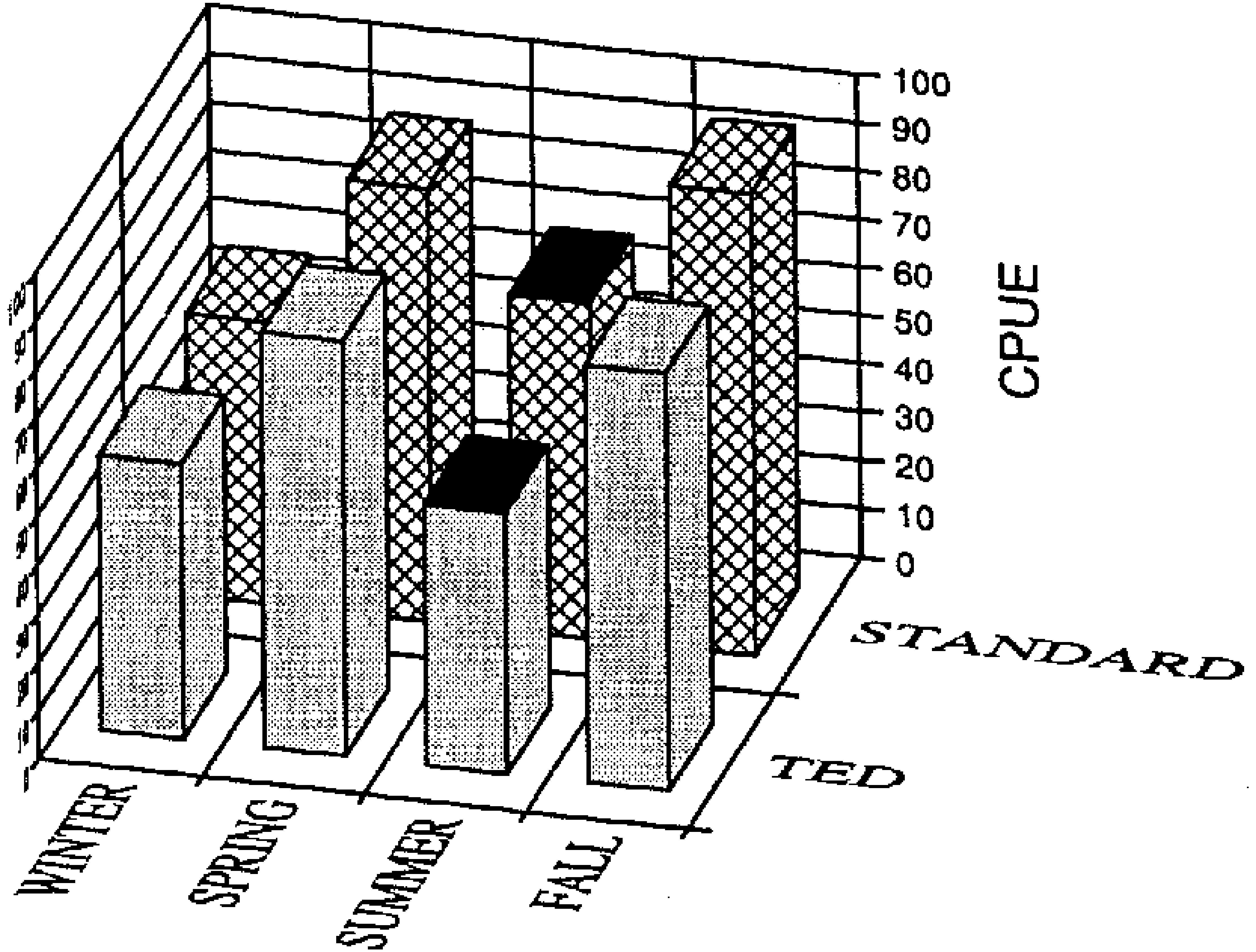


Figure 14. Differences in CPUE (lbs/hr) of finfish between standard and TED-equipped nets, by season. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706). Quad-rigged vessels only.

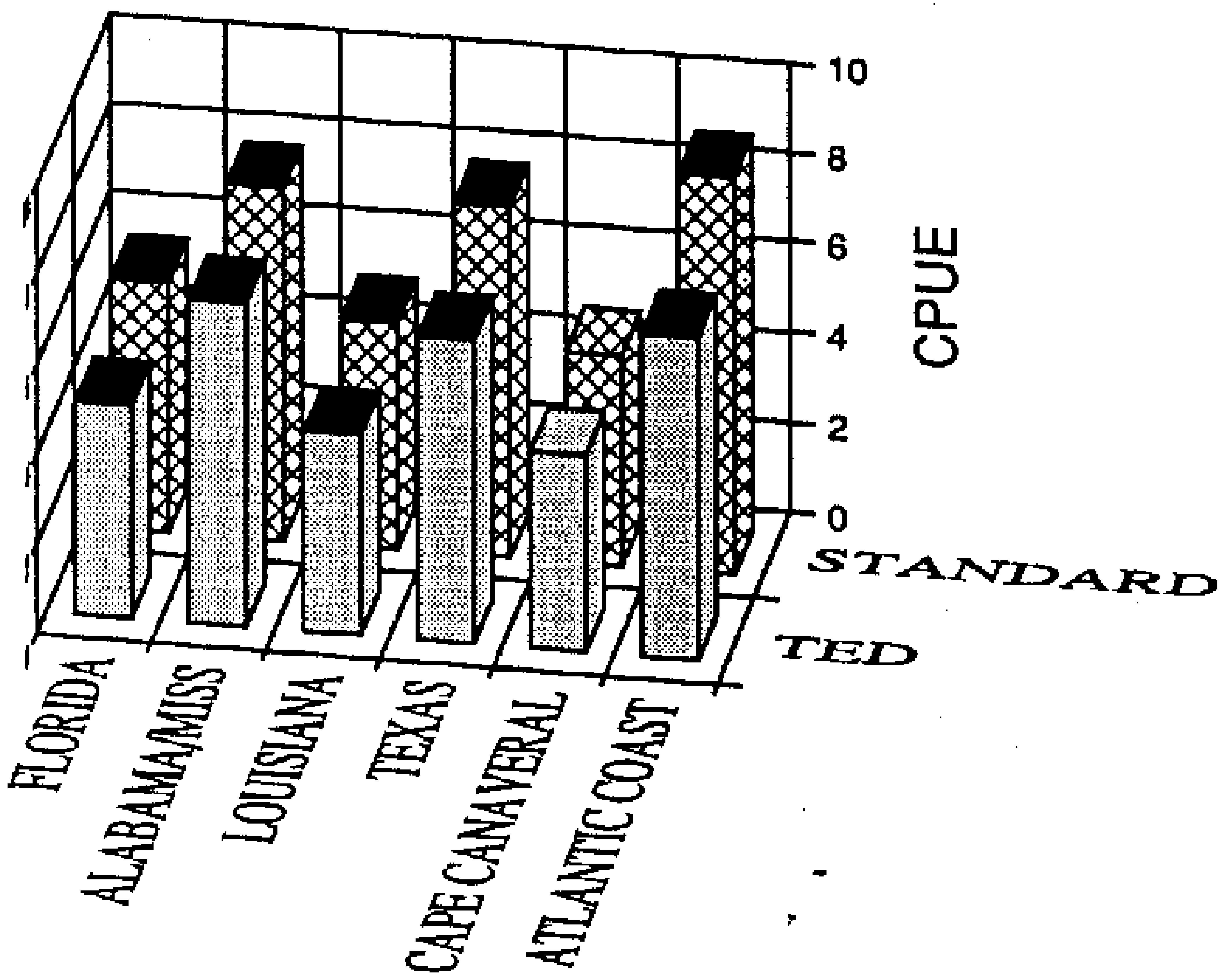


Figure 15. Differences in CPUE (lbs/hr) of shrimp between standard and TED-equipped nets, by area. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706). Quad-rigged vessels only.

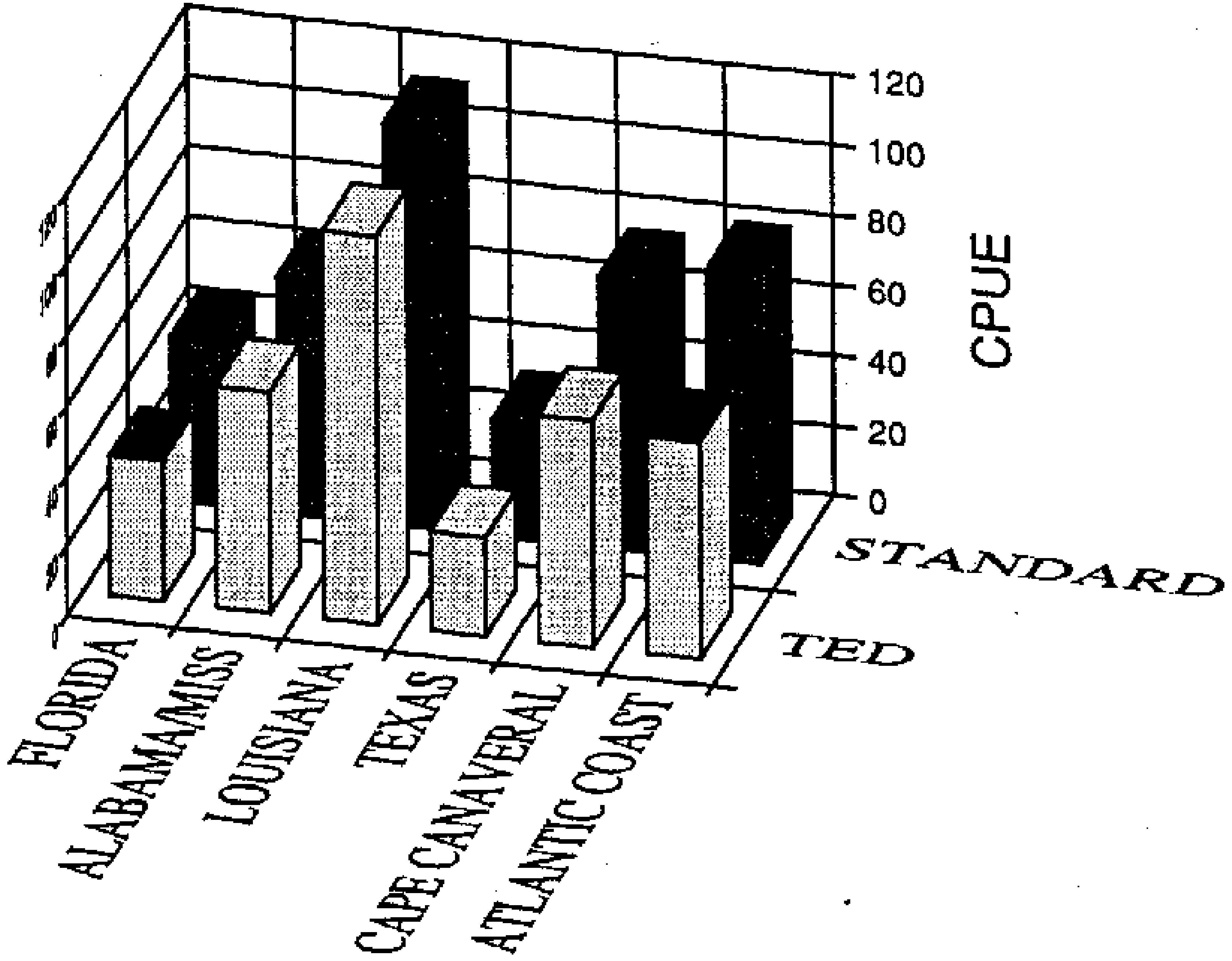


Figure 16. Differences in CPUE (lbs/hr) of finfish between standard and TED-equipped nets, by area. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706). Quad-rigged vessels only.

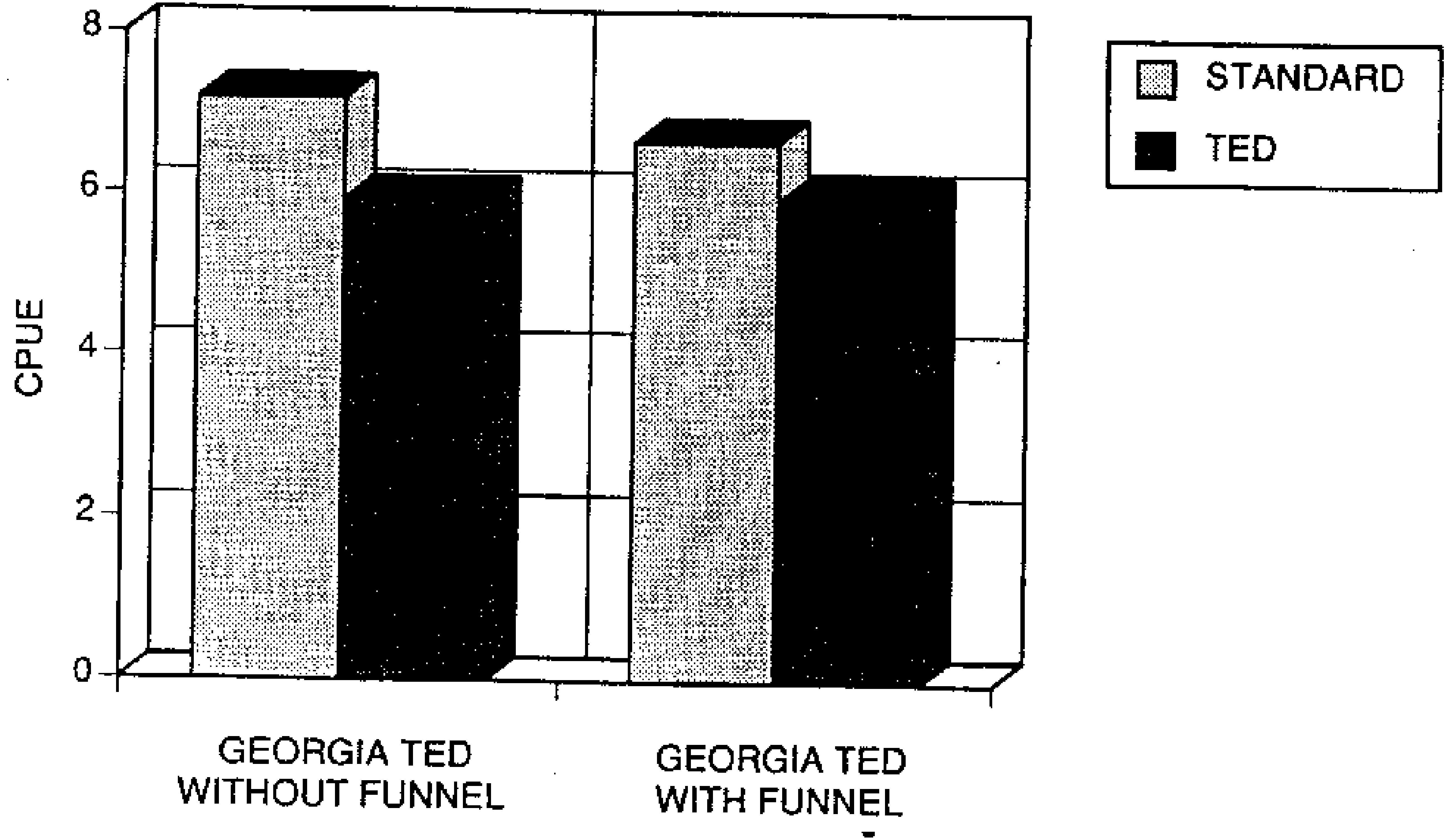


Figure 17. CPUE (lbs/hr) of shrimp in standard and TED-equipped nets for quad-rigged vessels. All areas and seasons combined. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706).

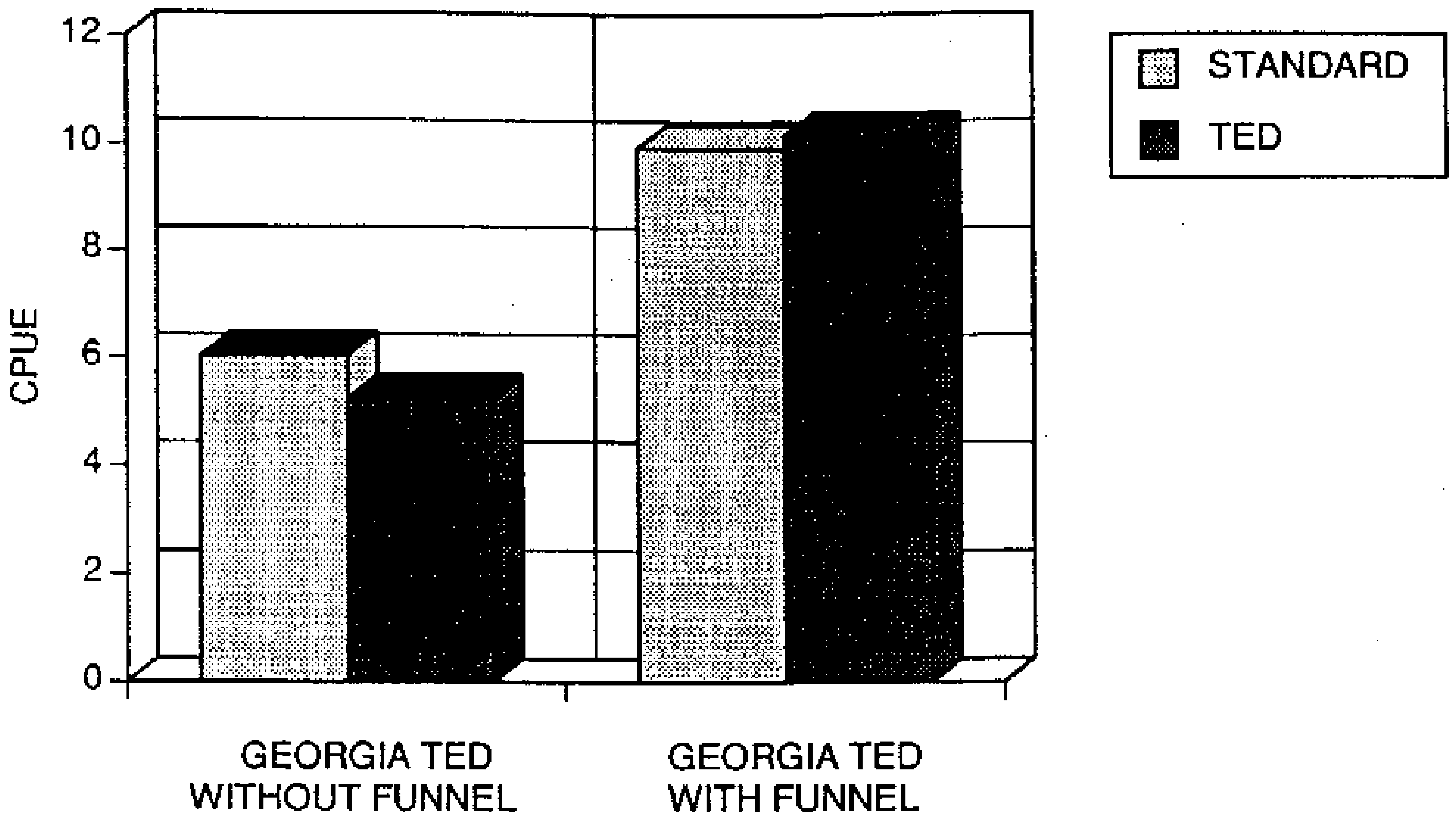


Figure 18. CPUE (lbs/hr) of shrimp in standard and TED-equipped nets for twin-rigged vessels. All areas and seasons combined. Solid topped bars represent significant differencesbetween standard and TED nets. Data paired by tows (N = 70).

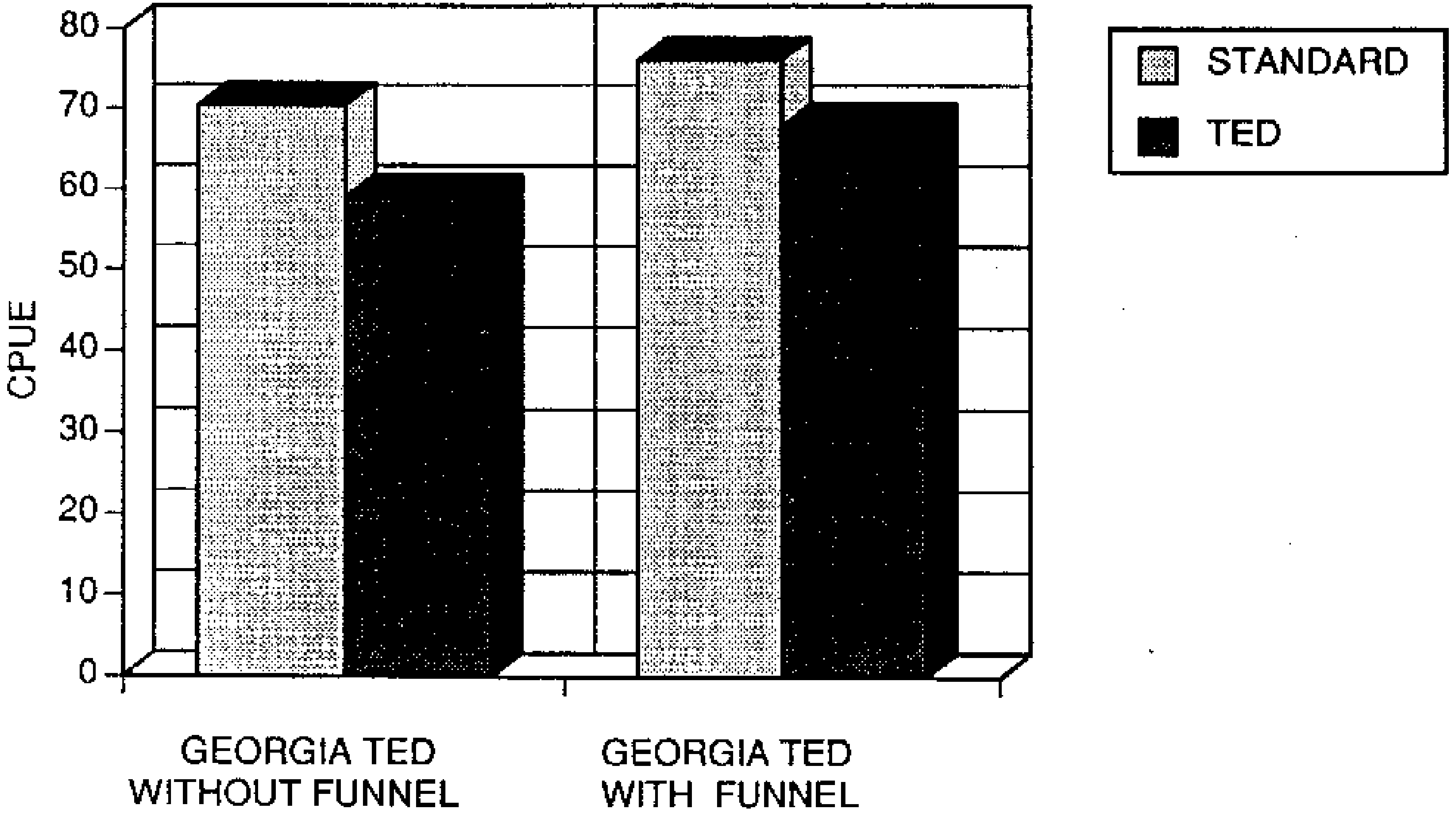


Figure 19. CPUE (lbs/hr) of finfish standard and TED-equipped nets for quad-rigged vessels. All areas and seasonscombined. Solid topped bars represent significant differences between standard and TED nets. Data paired by tows (N = 706).

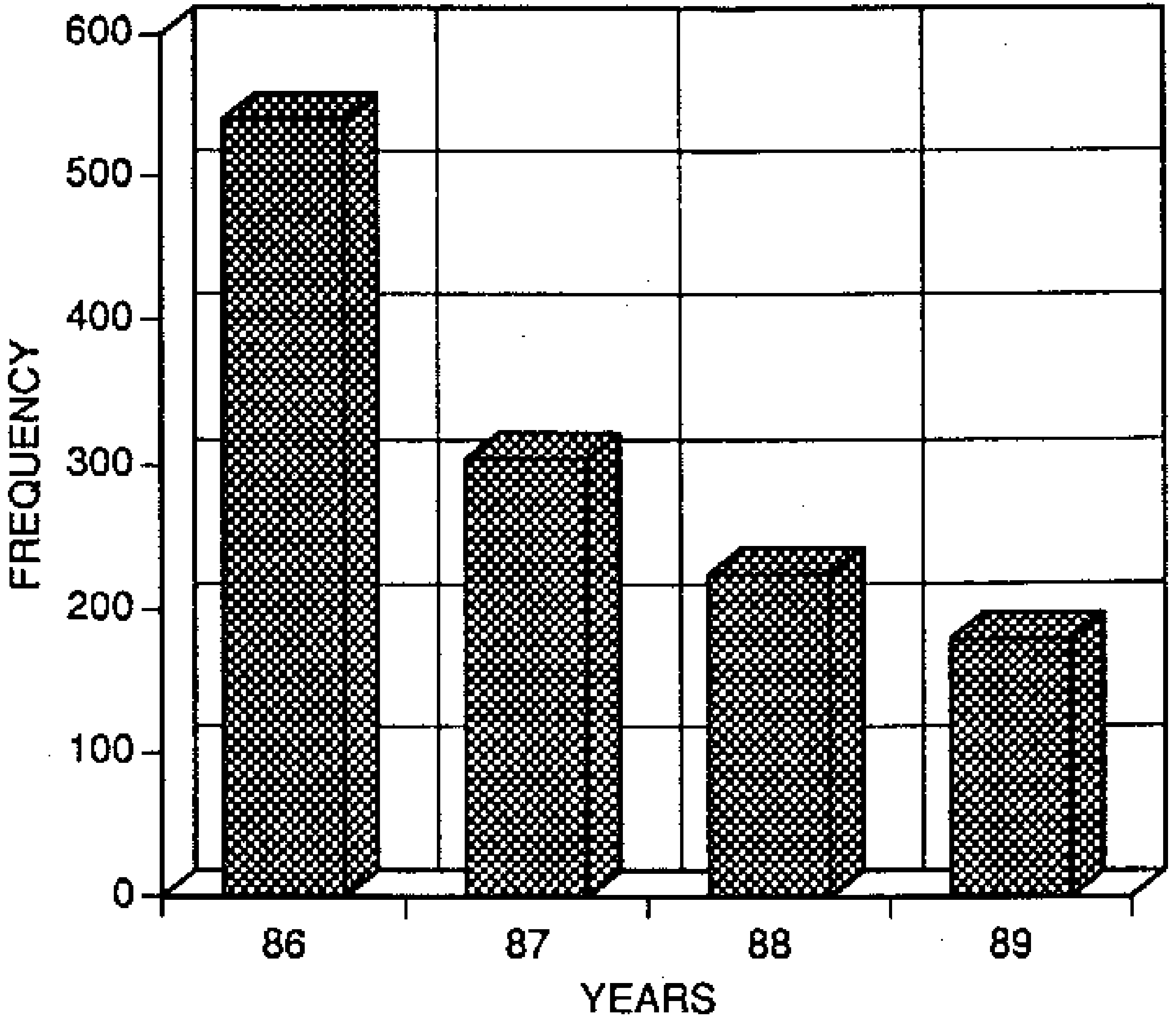


Figure 20. Turtle stranding frequency by year in statistical areas 17 - 21.

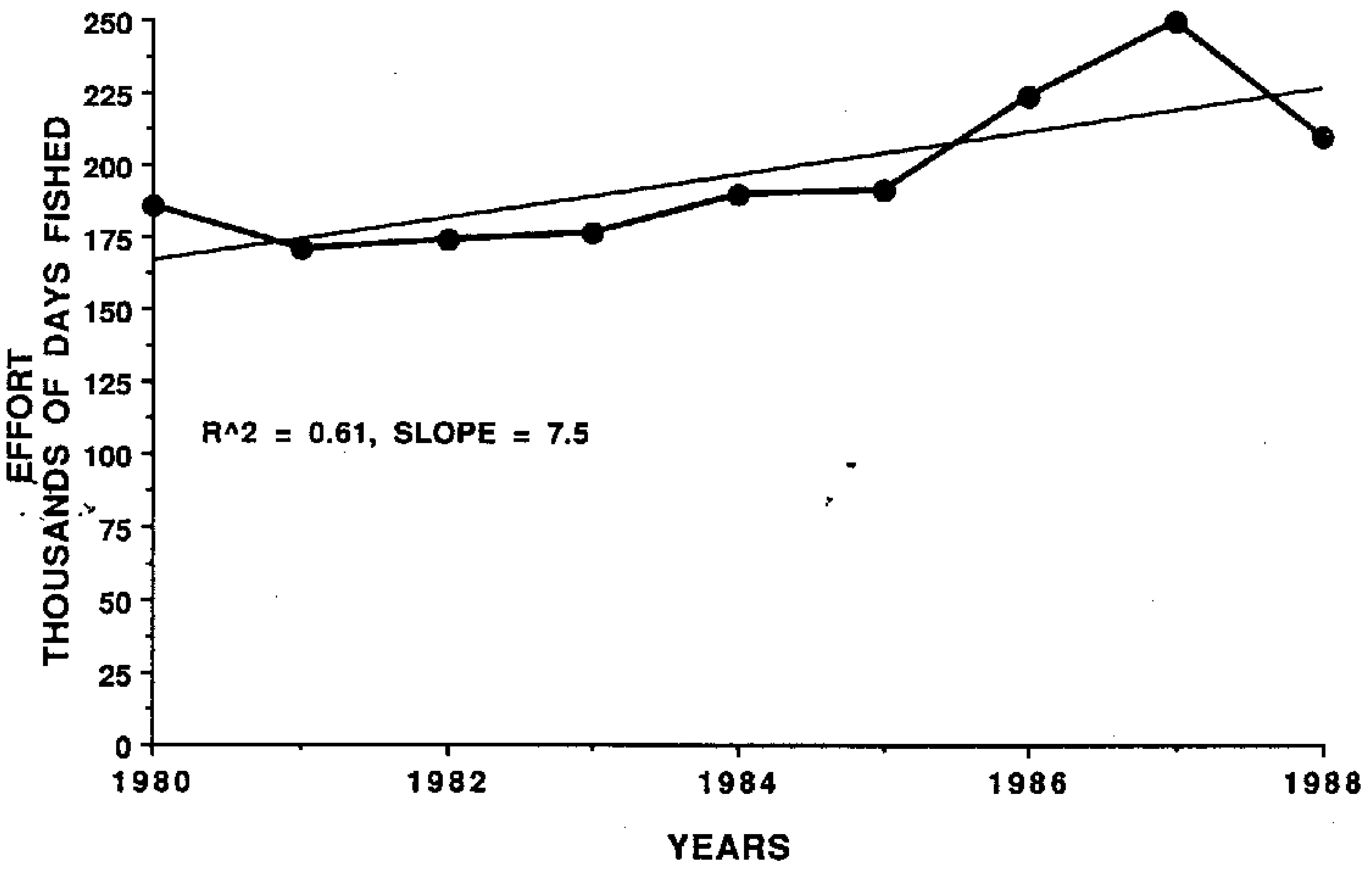


Figure 21. Effort in the offshore Gulf of Mexico shrimp fishery.

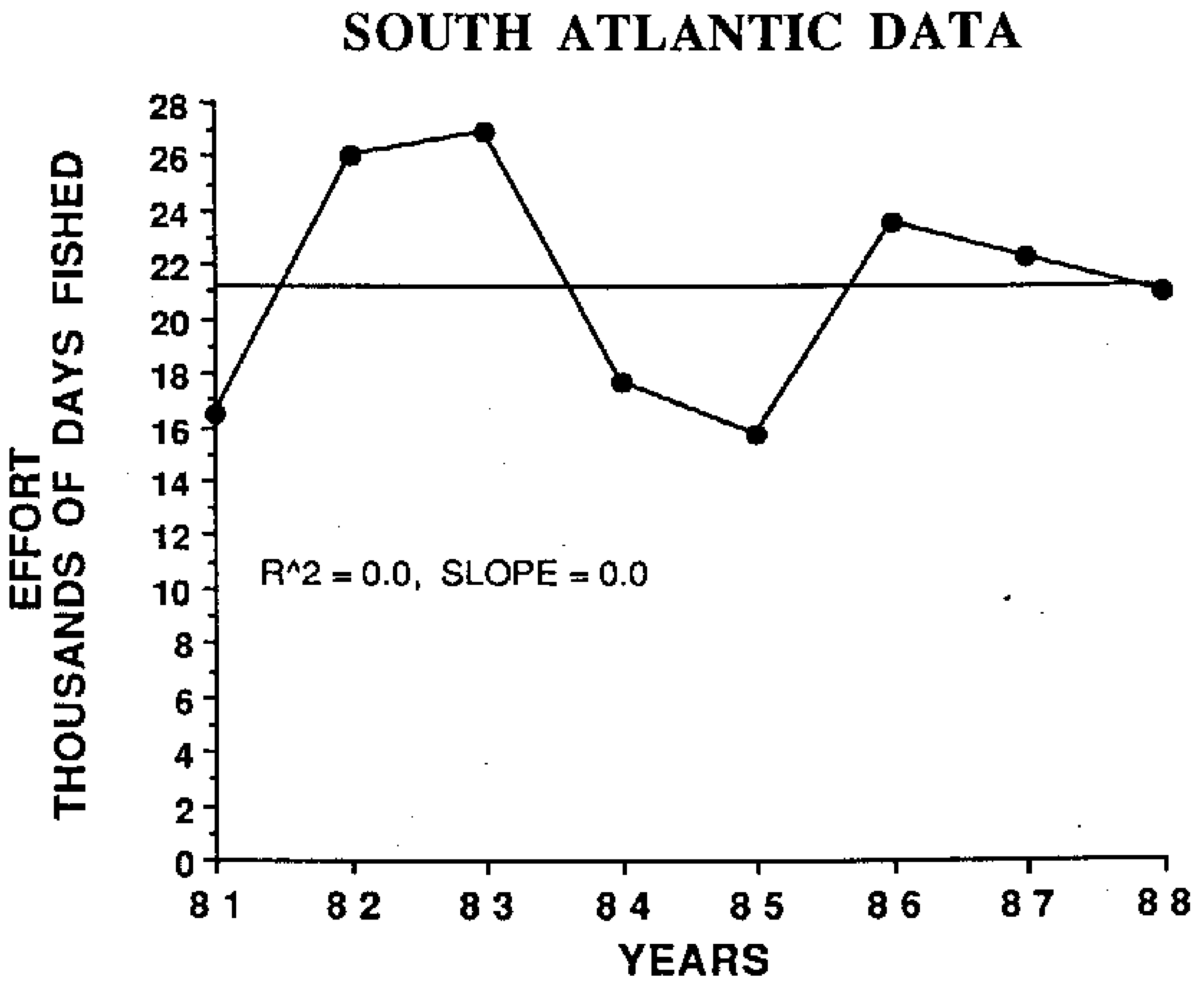


Figure 22. Effort in the offshore Atlantic shrimp fishery.

LIST OF APPENDICES

APPENDIX I

GENERAL LINEAR MODEL ANALYSES OF DATA FROM STANDARD AND TED-EQUIPPED TRAWLS PAIRED BY TOW AND BY TRIP, FOR QUAD-RIGGED AND TWIN-RIGGED TRAWLERS

METHODS

General linear model (GLM) analyses were performed on four data sets of paired TED-equipped and standard trawls, using SAS™ (Statistical Analysis System, SAS Institute, Inc., Cary, N.C.). The four data sets were represented by combinations of quad-rigged and twin-rigged trawlers with pairings by tow and by trip. The data paired by tow included TED-equipped and standard trawls towed simultaneously, one pair per tow. Pairing by trip produced one pair per trip. For quad-rigged trawlers, the pairs were standardized to one TED-equipped and one standard net by averaging the TED-equipped trawls together and the standard trawls together by tow. Pairing by trip involved summing over tows in a trip.

GLM analyses were used because all four data sets were unbalanced (Appendix I, Table 1); i.e., the number of observations was not the same for all levels of any given classification variable, and some combinations of classification variables contained no observations at all (they had empty cells). These analyses were used to "screen" the data sets to determine which GLM models were better suited to describe the data and underlying assumptions. They also can be compared with results of the multivariate, paired t-test described elsewhere in this report, since they were applied to the same four data sets. If either shrimp or fish data in a given pair were missing, then the record for that pair was rejected from the GLM analyses of paired data. For quad-rigged trawlers, there were 706 observations (pairs) by tow and 41 observations by trip. For twin-rigged trawlers, there were 64 observations by tow and 7 observations by trip.

Symbols used for dependent, classification and continuous variables in the GLM analyses of paired data are given below:

<u>Symbol</u>	<u>Description</u>
T	Two TED types including Georgia TED and Georgia TED with funnel;
R	Five regions represented by groupings of shrimp statistical subareas including Texas (18-21), Louisiana (13-17), Mississippi-Alabama (9-12), West Florida (1-8) and Atlantic coast (> 21).
Q	Four seasons represented by groupings of months into winter (Dec-Feb), Spring (Mar-May), Summer (Jun-Aug) and Autumn (Sep-Nov);
V	Towing velocity (knots);
H	Tow duration (hours);
ln(H)	Natural logarithm of H;

D	Water depth (fathoms);
$\ln(D)$	Natural logarithm of D;
S_T	Shrimp catch (pounds) per net tow or catch per trip in TED-equipped trawls;
S_S	Shrimp catch (pounds) per net tow or catch per trip in standard trawls;
S_{Tadj}	Shrimp catch (pounds) per net tow or catch per trip in TED-equipped trawls, adjusted by the addition of shrimp caught in the try net to the net immediately behind it;
S_{Sadj}	Shrimp catch (pounds) per net tow or catch per trip in standard trawls, adjusted by the addition of shrimp caught in the try net to the net immediately behind it;
F_T	Projected fish catch (pounds) per net tow or catch per trip in TED-equipped trawls (projected from the sample proportion of shrimp to fish and the shrimp catch);

F_S	Projected fish catch (pounds) per net tow or catch per trip in TED-equipped trawls (projected from the sample proportion of shrimp to fish and the shrimp catch);
$\ln(S_T)$	Natural logarithm of S_T;
$\ln(S_S)$	Natural logarithm of S_S;
$\ln(S_{Tadj})$	Natural logarithm of S_{Tadj};
$\ln(S_{Sadj})$	Natural logarithm of S_{Sadj};
$\ln(F_T)$	Natural logarithm of F_T;
$\ln(F_S)$	Natural logarithm of F_S;
$SCPUE_T$	Shrimp catch (pounds) per unit effort (hours) in TED-equipped trawls, S_T/H;
$SCPUE_S$	Shrimp catch (pounds) per unit effort (hours) in standard trawls, S_S/H;
$SCPUE_{Tadj}$	Shrimp catch (pounds) per unit effort (hours) in TED-equipped trawls, adjusted by the addition of shrimp caught in the try net to the net immediately behind it, S_{Tadj}/H;

$SCPUE_{Sadj}$	Shrimp catch (pounds) per unit effort (hours) in standard trawls, adjusted by the addition of shrimp caught in the try net to the net immediately behind it, S_{Sadj}/H;
$FCPUE_T$	Fish catch (pounds) per unit effort (hours) in TED-equipped trawls, F_T/H;
$FCPUE_S$	Fish catch (pounds) per unit effort (hours) in the standard trawls, F_S/H;
$\ln(SCPUE_T)$	Natural logarithm of $SCPUE_T$;
$\ln(SCPUE_S)$	Natural logarithm of $SCPUE_S$;
$\ln(SCPUE_{Tadj})$	Natural logarithm of $SCPUE_{Tadj}$;
$\ln(SCPUE_{Sadj})$	Natural logarithm of $SCPUE_{Sadj}$;
$\ln(FCPUE_T)$	Natural logarithm of $FCPUE_T$;
$\ln(FCPUE_S)$	Natural logarithm of $FCPUE_S$;

RS	Proportion that shrimp catch in TED-equipped trawls represented as compared to that in standard trawls, S_T/S_S;
RS_{adj}	Proportion that shrimp catch in TED-equipped trawls represented as compared to that in standard trawls, adjusted by the addition of the shrimp caught in the try net to the net immediately behind it, S_{Tadj}/S_{Sadj};
RF	Proportion that fish catch in TED-equipped trawls represented as compared to that in standard trawls, F_T/F_S;
LS	Percentage shrimp loss (note that a negative loss is a gain) by TED-equipped trawls, 100(1 - RS);
LS_{adj}	Percentage shrimp loss by TED-equipped trawls, adjusted by the addition of shrimp caught in the try net to the net immediately behind it, $100(1 - RS_{adj})$; and
LF	Percentage fish loss by TED-equipped trawls, 100(1 - RF).

The subscript T was used to designate TED-equipped trawls and the subscript S was used to designate standard trawls. The subscript adj was used to indicate data adjusted by the addition of catch from the try net to the net immediately behind it, whether the net was standard or TED-equipped. Thus, the adjustment applied only to one net in each quad-rigged tow or each twin-rigged tow.

Milliken and Johnson (1984) discussed the GLM methods, underlying assumptions, problems and interpretations for unbalanced experiments in multiway treatment structures with missing data. In the TED evaluation study, classification variables (main effects) such as TED type (T), Region (R) and Season (Q) represented the treatments. The analyses also considered continuous variables (covariates) such as duration of tow (H), towing speed (V) and water depth (D) or logarithmic transformations of H and D. The classification variables were the main effects and the continuous variables were covariates in the GLM models tested. Interactions were also included in some of the GLM models.

Such multiway treatment structure combined with all possible interactions produced large numbers of missing cells, so the sums of squares for some of the high order interactions were not estimable. Therefore, we included only three main effects and all 2-factor interactions in the model, when TED type, Region and Season were used together in a GLM analysis, and only one main effect and either all 2-factor or both 2-factor and 3-factor interactions when TED type, Region or Season were treated one at a time in separate analyses. However, all analyses in which TED type, Region and Season were included together in a GLM model were later discarded because the Least Squares Means (LSMs) for these classification variables were not estimable because of data imbalance.

GLM was used to determine which the models tested accounted for the greatest proportion of the total sum of squares as shown by the coefficient of variation (r^2), as well as to determine which models met the assumptions of mean zero and normality of the residuals. When they were estimable, LSMs also were estimated for each classification variable and were tested to determine if they were significantly different from zero. When the test involved a mean difference, whether constructed from untransformed or transformed data, this was equivalent to testing whether or not there was a significant difference between standard and TED-equipped trawls. When the test involved a proportion (ratio), this was equivalent to testing whether or not it differed significantly from zero.

The major problem impacting the GLM analyses of the paired data was the considerable imbalance of the data set. Some combinations of main effects were never observed; i.e., they had empty cells. Also, for those cells containing data, the number of observations was not equal from cell to cell. One simple example will suffice for explanation. Georgia TEDs without funnels and Georgia TEDs with funnels were the dominant TED types, so observations for other TEDs were excluded from the GLM analyses of paired data. Five Regions were defined as groupings of shrimp statistical subareas. For the experimental structure to have been balanced in regard to these two main effects of TED type and Region, both TED types should have been tested the same number of times in each Region. If one or the other TED type was not tested in a given Region, that combination of TED type and Region was not observed, thus causing an empty cell in the experimental structure. If given combinations of TED type and region contained data, but the number of observations varied from cell to cell, then the experiment was unbalanced with regard to sample size or the number of times a particular TED type by Region combination was tested. NMFS had little if any control over either type of imbalance (missing cells and unequal sample size), because the study involved voluntary participation by shrimpers who decided when and where to fish, so it was not a controlled experiment.

Many statistical packages can calculate test statistics for experiments with missing treatment combinations and unequal sample sizes, and SAS™ is among them. However, Milliken and Johnson (1984) remarked that they knew of no package [of statistical procedures] that handles the analysis of such data adequately or completely. Whenever there are missing treatment combinations, certain hypotheses involving the parameters corresponding to the missing cells generally cannot be tested without making some assumptions about these parameters (Milliken and Johnson, 1984).

For example, in the two-factor case involving missing cells in the combination of TED type and Region, the required assumption would be that there is no interaction between TED type and Region. Without experimental evidence to support this assumption, such an assumption should not be made. Thus, in the absence of evidence justifying an assumption of no interaction between main effects, we cannot validly make such an assumption. Because we were not able to build full models with all interactions (because of the tremendous imbalance in the data), it was not possible to obtain an experimental error term with which to test the higher order interactions for significance. Any main effects and interactions incorporated into our GLM analyses were tested against the residual mean square which could have included higher order interactions.

This residual mean square was an extremely crude "error" variance. In addition, because the F tests were not based on expected mean squares in some cases they may not have been exact or appropriate.

We used the "effects model" approach (Milliken and Johnson, 1984, Chapter 14) to GLM analysis. The Type IV analysis was chosen, since none of the main effects hypotheses tested by Types I-III analyses are entirely satisfactory when there are missing treatment combinations, because they rarely have reasonable interpretations. Type IV hypotheses are interpretable. However, the results obtained by Type IV analysis depend on what the treatments are called and how they are numbered. SAS™ GLM indicates this situation by placing an asterisk on the printed degrees of freedom and noting that "OTHER TYPE IV TESTABLE HYPOTHESES EXIST WHICH MAY YIELD DIFFERENT SS."

Another problem caused by the imbalanced data was that some LSMs were still not estimable, even when TED type, Region and Season were used one at a time in a model along with 2-factor and 3-factor interactions.

In a multivariate GLM with interactions, the term residual is used to denote variability remaining after the variation attributable to the main effects, covariates and interactions has been accounted for. In our models with one main effect, up to four continuous variables, and either all 2-factor or all 3-factor interactions, or both, the residual mean square could have contained variance components represented by higher order interactions as well as containing the so-called experimental error. If the assumption of zero interactions were incorrect for these higher order interactions, then the residual mean square would have been too large and the resulting F values for significance test would have been correspondingly too small (Milliken and Johnson, 1984). Consequently, if there were significant higher order interactions, they would not have been discovered by our analyses, and the significance of some main effects, covariates and lower order interactions included in our models might have been masked (ibid.). The consequence of this situation is that the significance tests of the LSMs were highly conservative. Thus, if a LSM was shown to be significantly different from zero, its significance occurred despite a potentially inflated residual mean square.

Assumptions of the GLM analysis are that (1) sampling within treatments (groups representing main effects) must be random, (2) the error term or residual must be an independent normally distributed, random variable with mean zero, (3) the variances of treatments must be homogeneous, and (4) the main effects must be additive.

RESULTS

Appendix I, Table 1 gives the number of observations for each level of each classification variable used in the GLM analyses. Part A is for data paired by tow and Part B for data paired by trip for quad-rigged trawlers. Part C is for data paired by tow and Part D for data paired by trip for twin-rigged trawlers. The imbalance is obvious in these data.

Appendix I, Table 2 gives the descriptive statistics for all dependent and continuous variables used in our GLM analyses, for data paired by tow (A) and by trip (B) for quad-rigged trawlers, and by tow (C) and by trip (D) for twin-rigged trawlers.

Appendix I, Table 3 shows the particular dependent and independent variables used in each GLM analysis on data paired by tow and by trip for quad-rigged and twin-rigged trawlers, and the variance of residuals (s^2), coefficient of determination (r^2), and analysis of the residuals (coefficients of skewness and kurtosis) for each. Analysis of the residuals indicated the degree to which a chosen model fulfilled the requirements of a mean of zero and normality of the residuals required by GLM analysis. The coefficient of determination indicated the proportion of variation in the dependent variable that was accounted for by the independent variables and interactions in each model tested. Note that for data paired by trip, tow velocity and water depth could not be included as continuous variables because they varied from tow to tow in a trip.

Appendix I, Table 4 gives the LSMs for each dependent variable by TED type, Region and Season, for data paired by tow and by trip for quad-rigged and twin-rigged trawlers. An "ns" next to a LSM indicates that it was not significantly different from zero at $P \leq 0.05$. Non-significance was the exception rather than the rule, since most LSMs were significantly different from zero. An "NE" in the table indicated that the LSM was not estimable because of data imbalance. Occasionally, these significance tests produced what might appear to be ambiguous results; e.g., one LSM might have been significantly different from zero, while another of the same magnitude or larger might not have been significantly different from zero. This was another result of the imbalance in the data since significance depends in part on degrees of freedom associated with the test statistic, and the sample size was not the same for all levels of a given classification variable (See Appendix I, Table 1).

In most cases the GLM models that produced the highest coefficients of determination (r^2) and the lowest skewness and kurtosis coefficients for the residuals were those involving the difference between the natural logarithms of shrimp catches in standard vs TED-equipped trawls, both with and without the try net correction (Appendix I, Table 3). Appendix I, Table 4 shows which LSMs were significantly different from zero and which were not for various levels of TED type, Region and Season.

The LSMs of the ratios of shrimp catches were all significantly different from zero, for both TED-types, all Regions and all Seasons, both with and without the try net correction (Appendix I, Table 4). When the dependent variable involved a difference between standard and TED-equipped nets, whether or not logarithms had been used, the LSM was an estimate of the mean difference. If this LSM was significantly from zero it indicated that there was a significant difference between standard and TED-equipped nets. The sign of this difference indicated whether TEDs lost (+) or gained (-) shrimp as compared to standard nets.

The GLM analyses as well as other analyses applied to data paired by tow should be considered superior to those applied to data paired by trip. First of all, the sampling unit in the TED evaluation study was the individual tow, not the trip (Appendix I, Table 3). Secondly, pairing by trip collapsed the data from individual tows in a trip into one pair per trip, thus reducing sample size and masking tow to tow variation. Finally, pairing by trip produced inconsistent results, increasing the coefficients of determination for some GLM analyses but decreasing them for others as compared to results for GLM analyses of data paired by tow.

Appendix I. Table 1. Frequency of levels within classification variables used in GLM analyses of paired observations from TED-equipped and standard trawls.

A. Data paired by tow (706 observations, quad-rigged trawlers)

1.

TED type	Frequency
Georgia TED	256
Georgia TED with funnel	450
Total	706

2.

Region	Frequency
18-21	112
13-17	154
9-12	88
1-8	106
$\geq$ 21	246
Total	706

3.

Season	Frequency
Dec.-Feb.	142
Mar.-May	148
June-Aug.	340
Sept.-Nov.	76
Total	706

Appendix I. Table 1. (cont.)

4. Combined

Georgia TED

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	0	0	0	0
13-17	0	0	21	0
9-12	0	0	0	0
1-8	0	10	0	0
≥21	60	0	165	0
Total	60	10	186	0

Georgia TED with funnel

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	3	1	88	20
13-17	34	55	25	19
9-12	28	3	20	37
1-8	17	79	0	0
≥21	0	0	21	0
Total	82	138	154	76

Appendix I. Table 1. (cont.)

B. Data paired by trip (41 observations, quad-rigged trawlers)

1.

TED type	Frequency
Georgia TED	17
Georgia TED with funnel	24
Total	41

2.

Region	Frequency
18-21	10
13-17	4
9-12	5
1-8	6
>21	16
Total	41

3.

Season	Frequency
Dec.-Feb.	10
Mar.-May	6
June-Aug.	23
Sept.-Nov.	2
Total	41

4. Combined

Georgia TED

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	0	0	0	0
13-17	0	0	1	0
9-12	0	0	0	0
1-8	0	1	0	0
>21	4	0	11	0
Total	4	1	12	0

Appendix I. Table 1. (cont.)

Georgia TED with funnel

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	1	1	8	0
13-17	1	1	1	0
9-12	2	0	1	2
1-8	2	3	0	0
≥21	0	0	1	0
Total	6	5	11	2

Appendix I. Table 1. (cont.)

C. Data paired by tow (64 observations, twin-rigged trawlers). Six observations were excluded from the analyses because fish data were not collected on 6 tows.

1.

TED type	Frequency
Georgia TED	28
Georgia TED with funnel	36
Total	64

2.

Region	Frequency
18-21	64
13-17	0
9-12	0
1-8	0
>21	0
Total	64

3.

Season	Frequency
Dec.-Feb.	5
Mar.-May	0
June-Aug.	0
Sept.-Nov.	59
Total	64

Appendix I. Table 1. (cont.)

4. Combined

Georgia TED

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	5	0	0	23
13-17	0	0	0	0
9-12	0	0	0	0
1-8	0	0	0	0
≥21	0	0	0	0
Total	5	0	0	23

Georgia TED with funnel

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	0	0	0	36
13-17	0	0	0	0
9-12	0	0	0	0
1-8	0	0	0	0
≥21	0	0	0	0
Total	0	0	0	36

Appendix I. Table 1. (cont.)

D. Data paired by trip (7 observations, twin-rigged trawlers)

1\.

TED type	Frequency
Georgia TED	3
Georgia TED with funnel	4
Total	7

2\.

Region	Frequency
18-21	7
13-17	0
9-12	0
1-8	0
>21	0
Total	7

3\.

Season	Frequency
Dec.-Feb.	1
Mar.-May	0
June-Aug.	0
Sept.-Nov.	6
Total	7

Appendix I. Table 1. (cont.)

4. Combined

Georgia TED

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	1	0	0	2
13-17	0	0	0	0
9-12	0	0	0	0
1-8	0	0	0	0
≥21	0	0	0	0
Total	1	0	0	2

Georgia TED with funnel

Region/Season	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
18-21	0	0	0	4
13-17	0	0	0	0
9-12	0	0	0	0
1-8	0	0	0	0
≥21	0	0	0	0
Total	0	0	0	4

Appendix I. Table 2. Descriptive statistics for dependent and continuous variables used in GLM analyses of paired observations, from TED-equipped and standard trawls.

A. Data paired by tow (706 observations, quad-rigged trawlers)

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
S_T	24.0	477.8	0.6	203	2.22	8.41
S_{Tadj}	24.3	499.6	0.6	223	2.42	10.85
S_S	26.0	577.3	0.3	232	2.48	10.81
S_{Sadj}	27.4	631.0	0.3	232	2.31	8.96
F_T	276	120,878	3.8	5,086	5.29	54.89
F_S	299	103,580	4.2	3,575	3.26	19.04
$SCPUE_T$	5.88	26.6	0.1	32.0	1.84	3.94
$SCPUE_{Tadj}$	5.94	27.1	0.1	32.0	1.84	3.95
$SCPUE_S$	6.53	37.1	0.2	58.5	2.41	9.85
$SCPUE_{Sadj}$	6.86	41.0	0.2	63.1	2.46	10.63
$FCPUE_T$	64.5	5,033	2.0	1,060	5.28	57.42
$FCPUE_S$	74.0	6,408	2.2	1,005	4.28	34.46
S_S-S_T	2.01	53.2	-27.5	77.6	2.96	22.78
$S_{Sadj}-S_{Tadj}$	3.13	53.2	-22.8	72.6	3.41	22.97
F_S-F_T	22.9	33,658	-1,511	1,255	-0.45	16.67
$SCPUE_S-SCPUE_T$	0.65	4.41	-4.7	26.5	4.45	38.96
$SCPUE_{Sadj}-SCPUE_{Tadj}$	0.92	5.07	-3.8	31.2	5.32	52.50
$FCPUE_S-FCPPUE_T$	9.44	2776	-314.8	826.0	5.57	86.68
$\ln(S_T)$	2.80	0.87	-0.5	5.3	-0.49	0.53
$\ln(S_{Tadj})$	2.81	0.87	-0.5	5.4	-0.48	0.55
$\ln(S_S)$	2.89	0.84	-1.2	5.4	-0.50	0.85
$\ln(S_{Sadj})$	2.94	0.85	-1.2	5.4	-0.50	0.86
$\ln(F_T)$	5.11	1.10	1.3	8.5	-0.34	0.59
$\ln(F_S)$	5.24	1.05	1.4	8.2	-0.55	0.93
$\ln(S_S)-\ln(S_T)$	0.09	0.06	-0.7	1.2	0.82	1.98
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.13	0.06	-0.8	1.3	0.90	2.71
$\ln(F_S)-\ln(F_T)$	0.13	0.20	-1.1	2.1	0.76	1.68

Appendix I. Table 2 (cont).

Variable coefficent	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis
$\ln(SCPUE_S)-\ln(SCPUE_T)$	0.09	0.06	-0.7	1.2	0.82	1.98
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	0.13	0.06	-0.8	1.3	0.90	2.71
$\ln(FCPUE_S)-\ln(FCPUE_T)$	0.13	0.20	-1.1	2.1	0.76	1.68
RS	0.94	0.05	0.3	2.0	0.48	2.59
RS_{adj}	0.90	0.04	0.3	2.2	0.67	4.75
RF	0.96	0.16	0.1	3.1	1.01	2.45
RSCPUE	0.94	0.05	0.3	2.0	0.48	2.59
$RSCPUE_{adj}$	0.90	0.04	0.3	2.2	0.67	4.75
RFCPUE	0.96	0.16	0.1	3.1	1.01	2.45
LS	5.66	500	-100.0	70.0	-0.48	2.59
LS_{adj}	9.65	429	-119.2	73.5	-0.67	4.75
LF	4.17	1,572	-210.9	88.3	-1.01	2.45
H	4.46	4.87	0.7	14.1	1.06	1.76
D	11.2	78.5	1.0	50.0	1.60	2.69
V	2.48	0.38	1.5	4.7	-0.41	-0.69
ln(H)	1.37	0.27	-0.4	2.6	-0.40	0.08
ln(D)	2.14	0.55	0.0	3.9	0.12	-0.70

Appendix I. Table 2 (cont).

B. Data paired by trip (41 observations, quad-rigged trawlers)

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
S_T	422	160,978	1.6	1,765	1.29	1.57
S_{Tadj}	428	167,721	1.7	1,869	1.42	2.28
S_S	458	195,495	1.6	2,108	1.61	3.37
S_{Sadj}	482	211,113	1.6	2,108	1.46	2.48
F_T	4,753	60,189,985	56.1	45,702	4.01	19.67
F_S	5,148	63,543,573	51.6	46,645	3.90	18.62
$SCPUE_T$	5.82	19.3	0.2	16.4	1.17	0.47
$SCPUE_{Tadj}$	5.88	19.4	0.2	16.4	1.17	0.47
$SCPUE_S$	6.43	21.8	0.4	19.2	1.09	0.47
$SCPUE_{Sadj}$	6.80	24.1	0.4	20.1	1.06	0.32
$FCPUE_T$	47.2	1,082	4.0	152.9	1.32	2.59
$FCPUE_S$	54.4	1,309	8.8	156.1	0.95	0.58
S_S-S_T	35.2	6,662	-125.0	343.0	1.68	4.40
$S_{Sadj}-S_{Tadj}$	54.3	5,630	-82.0	274.4	1.22	1.37
F_S-F_T	394	1,141,324	-2,796	4,251	0.49	5.29
$SCPUE_S-SCPUE_T$	0.60	1.05	-0.6	3.3	1.27	0.96
$SCPUE_{Sadj}-SCPUE_{Tadj}$	0.92	1.08	-0.4	3.7	1.22	1.02
$FCPUE_S-FCPPUE_T$	7.26	143.0	-15.8	45.2	1.04	2.11
$\ln(S_T)$	5.38	2.29	0.4	7.5	-1.41	2.30
$\ln(S_{Tadj})$	5.40	2.26	0.5	7.5	-1.41	2.26
$\ln(S_S)$	5.49	2.15	0.5	7.7	-1.51	2.96
$\ln(S_{Sadj})$	5.55	2.10	0.5	7.7	-1.49	3.06
$\ln(F_T)$	7.51	2.60	4.0	10.7	-0.57	-0.11
$\ln(F_S)$	7.68	2.27	3.9	10.8	-0.53	-0.09
$\ln(S_S)-\ln(S_T)$	0.11	0.03	-0.2	0.6	0.97	0.57
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.16	0.03	-0.1	0.6	0.86	0.57
$\ln(F_S)-\ln(F_T)$	0.17	0.11	-0.3	1.3	1.64	3.97

Appendix I. Table 2 (cont).

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
$\ln(SCPUE_S) - \ln(SCPUE_T)$	0.11	0.03	-0.2	0.6	0.97	0.57
$\ln(SCPUE_{Sadj}) - \ln(SCPUE_{Tadj})$	0.16	0.03	-0.1	0.6	0.86	0.57
$\ln(FCPUE_S) - \ln(FCPUE_T)$	0.17	0.11	-0.3	1.3	1.64	3.97
RS	0.91	0.02	0.5	1.2	-0.55	-0.06
RS_{adj}	0.87	0.02	0.5	1.1	-0.45	-0.14
RF	0.88	0.06	0.3	1.4	-0.26	0.82
RSCPUE	0.91	0.02	0.5	1.2	-0.55	-0.06
$RSCPUE_{adj}$	0.87	0.02	0.5	1.1	-0.45	-0.14
RFCPUE	0.88	0.06	0.3	1.4	-0.26	0.82
LS	9.32	230	-16.6	45.2	0.55	-0.06
LS_{adj}	13.4	177	-10.3	45.2	0.45	-0.14
LF	11.8	588	-40.2	72.3	0.26	0.82
H	79.48	5,203	3.8	298.9	1.39	1.37
ln(H)	3.93	1.14	1.3	5.7	-0.67	0.42

Appendix I. Table 2 (cont).
C. Data paired by tow (64 observations, twin-rigged trawlers)

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
S_T	23.8	503	0.6	151.9	3.33	16.33
S_{Tadj}	24.2	501	0.6	151.9	3.32	16.29
S_S	23.9	282	0.6	77.2	1.29	1.68
S_{Sadj}	25.2	323	0.6	86.1	1.39	2.03
F_T	51.3	3,563	4.4	396.7	3.65	17.92
F_S	51.0	2,117	6.6	276.7	2.63	9.53
$SCPUE_T$	8.22	95.3	0.8	76.0	5.48	37.46
$SCPUE_{Tadj}$	8.30	94.7	0.8	76.0	5.51	37.76
$SCPUE_S$	7.87	31.7	0.8	35.4	2.11	7.87
$SCPUE_{Sadj}$	8.37	41.5	0.8	43.0	2.68	12.17
$FCPUE_T$	16.7	279	1.2	92.3	2.63	8.46
$FCPUE_S$	17.0	173	2.2	64.3	1.56	2.25
S_S-S_T	0.08	129	-81.0	15.2	-5.85	42.25
$S_{Sadj}-S_{Tadj}$	0.99	93.7	-65.8	16.8	-5.25	36.76
F_S-F_T	-0.37	1,720	-176.4	147.1	-1.08	7.22
$\ln(S_T)$	2.84	0.75	-0.5	5.0	-0.77	2.76
$\ln(S_{Tadj})$	2.86	0.75	-0.5	5.0	-0.83	2.90
$\ln(S_S)$	2.89	0.74	-0.5	4.3	-1.28	3.26
$\ln(S_{Sadj})$	2.94	0.73	-0.5	4.5	-1.26	3.46
$\ln(F_T)$	3.52	0.82	1.5	6.0	0.16	-0.02
$\ln(F_S)$	3.62	0.63	1.9	5.6	0.04	-0.30
$\ln(S_S)-\ln(S_T)$	0.05	0.06	-0.8	0.7	-0.56	2.30
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.08	0.05	-0.6	0.7	-0.49	1.43
$\ln(F_S)-\ln(F_T)$	0.10	0.43	-1.6	1.7	0.10	0.15
$SCPUE_S-SCPUE_T$	-0.35	27.9	-40.5	4.4	-7.15	55.00
$SCPUE_{Sadj}-SCPUE_{Tadj}$	0.07	19.5	-32.9	5.9	-6.78	51.33
$FCPUE_S-FCPUE_T$	0.30	170	-63.0	35.0	-1.70	8.70

Appendix I. Table 2 (cont).

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
$\ln(SCPUE_S) - \ln(SCPUE_T)$	0.05	0.06	-0.8	0.7	-0.56	2.30
$\ln(SCPUE_{Sadj}) - \ln(SCPUE_{Tadj})$	0.08	0.05	-0.6	0.7	-0.49	1.43
$\ln(FCPUE_S) - \ln(FCPUE_T)$	0.10	0.43	-1.6	1.7	0.10	0.15
RS	0.98	0.08	0.5	2.1	2.02	6.67
RS_{adj}	0.94	0.05	0.5	1.8	1.46	3.34
RF	1.11	0.62	0.2	4.8	2.16	7.17
RSCPUE	0.98	0.08	0.5	2.1	2.02	6.67
$RSCPUE_{adj}$	0.94	0.05	0.5	1.8	1.46	3.34
RFCPUE	1.11	0.62	0.2	4.8	2.16	7.17
LS	2.05	756	-114.2	48.8	-2.02	6.67
LS_{adj}	5.76	487	-76.4	48.6	-1.46	3.34
LF	-11.2	6167	-384.3	81.7	-2.16	7.17
H	3.20	1.94	0.8	6.9	0.58	-0.08
D	4.56	5.30	1.0	13.0	0.82	1.80
V	2.42	0.02	2.0	2.5	-1.34	0.83
ln(H)	1.06	0.22	-0.2	1.9	-0.47	-0.02
ln(D)	1.37	0.36	0.0	2.6	-0.89	0.49

Appendix I. Table 2 (cont).

D. Data paired by trip (7 observations, twin-rigged trawlers)

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
S_T	228	12,190	136.7	419.8	1.22	-0.12
S_{Tadj}	232	11,665	136.7	419.8	1.23	-0.05
S_S	233	4,995	155.0	349.2	0.82	-0.55
S_{Sadj}	244	5,533	171.9	359.5	0.87	-1.02
F_T	471	67,015	151.4	904.6	0.44	-0.19
F_S	466	34,534	157.6	685.7	-0.59	-0.42
$SCPUE_T$	7.74	22.7	3.9	17.0	1.59	1.77
$SCPUE_{Tadj}$	7.83	22.0	4.3	17.0	1.63	1.88
$SCPUE_S$	7.70	8.82	4.7	12.3	1.01	-0.80
$SCPUE_{Sadj}$	8.13	10.68	4.7	13.5	1.02	-0.43
$FCPUE_T$	14.7	59.0	6.3	29.9	1.37	2.65
$FCPUE_S$	14.7	28.3	6.5	20.0	-0.50	-1.41
S_S-S_T	4.26	3,010	-116.0	45.9	-2.29	5.59
$S_{Sadj}-S_{Tadj}$	12.7	1,998	-85.6	40.3	-2.33	5.67
F_S-F_T	-5.49	32,870	-339.5	178.4	-1.25	0.82
$SCPUE_S-SCPUE_T$	0.04	4.38	-4.7	1.4	-2.44	6.18
$SCPUE_{Sadj}-SCPUE_{Tadj}$	0.31	2.93	-3.5	1.4	-2.34	5.75
$FCPUE_S-FCPUE_T$	0.08	36.4	-11.2	7.2	-1.15	1.42
$\ln(S_T)$	5.34	0.19	4.9	6.0	0.95	-0.80
$\ln(S_{Tadj})$	5.36	0.18	4.9	6.0	0.94	-0.67
$\ln(S_S)$	5.41	0.09	5.0	5.9	0.46	-0.98
$\ln(S_{Sadj})$	5.46	0.08	5.1	5.9	0.65	-1.29
$\ln(F_T)$	6.00	0.39	5.0	6.8	-0.50	-0.81
$\ln(F_S)$	6.05	0.26	5.1	6.5	-1.40	1.92
$\ln(S_S)-\ln(S_T)$	0.07	0.04	-0.3	0.2	-1.83	3.79
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.10	0.03	-0.2	0.2	-1.76	3.23
$\ln(F_S)-\ln(F_T)$	0.05	0.11	-0.5	0.4	-0.59	-0.86

Appendix I. Table 2 (cont).

Variable	Mean	Variance	Min.	Max.	Skewness coefficent	Kurtosis coefficent
$\ln(SCPUE_S) - \ln(SCPUE_T)$	0.07	0.04	-0.3	0.2	-1.83	3.79
$\ln(SCPUE_{Sadj}) - \ln(SCPUE_{Tadj})$	0.10	0.03	-0.2	0.2	-1.76	3.23
$\ln(FCPUE_S) - \ln(FCPUE_T)$	0.05	0.11	-0.5	0.4	-0.59	-0.86
RS	0.95	0.04	0.8	1.4	2.08	4.71
RS_{adj}	0.92	0.03	0.8	1.3	1.96	4.07
RF	1.00	0.13	0.6	1.6	0.96	-0.43
RSCPUE	0.95	0.04	0.8	1.4	2.08	4.71
$RSCPUE_{adj}$	0.92	0.03	0.8	1.3	1.96	4.07
RFCPUE	1.00	0.13	0.6	1.6	0.96	-0.43
LS	5.03	407	-38.2	21.3	-2.08	4.71
LS_{adj}	8.22	258	-25.6	20.5	-1.96	4.07
LF	-0.40	1,289	-60.1	36.0	-0.96	-0.43
H	31.5	49.8	24.2	42.6	0.71	-0.89
ln(H)	3.43	0.05	3.2	3.8	0.48	-1.17

Appendix I. Table 3. Results of General Linear Model (GLM) analyses of paired observations from TED-equipped and standard trawls with TED type (T), Region (R) and Season (Q) as classification variables and with selected continuous variables as covariates (see Appendix I text for description of symbols used for dependent and continuous variables).

A. Data paired by tow (706 observations, quad-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$S_S - S_T$	T	F_S-F_T, H, D, V	all 2-factor and 3-factor	48.12	0.128	2.87	25.52
$S_{Sadj}-S_{Tadj}$	T	F_S-F_T, H, D, V	"	47.67	0.135	3.15	22.47
$S_S - S_T$	R	F_S-F_T, H, D, V	"	44.72	0.229	2.32	16.82
$S_{Sadj}-S_{Tadj}$	R	F_S-F_T, H, D, V	"	46.87	0.191	2.72	17.16
$S_S - S_T$	Q	F_S-F_T, H, D, V	"	45.80	0.197	2.21	18.25
$S_{Sadj}-S_{Tadj}$	Q	F_S-F_T, H, D, V	"	46.43	0.185	2.67	18.14
$SCPUE_S-SCPUE_T$	T	$FCPUE_S-FCPUE_T$, D, V	"	3.44	0.237	2.40	12.80
$SCPUE_{Sadj}-SCPUE_{Tadj}$	T	$FCPUE_S-FCPUE_T$, D, V	"	3.86	0.253	2.75	15.18
$SCPUE_S-SCPUE_T$	R	$FCPUE_S-FCPUE_T$, D, V	"	3.73	0.198	3.97	37.07
$SCPUE_{Sadj}-SCPUE_{Tadj}$	R	$FCPUE_S-FCPUE_T$, D, V	"	4.35	0.184	4.68	49.02
$SCPUE_S-SCPUE_T$	Q	$FCPUE_S-FCPUE_T$, D, V	"	3.83	0.167	3.80	36.47
$SCPUE_{Sadj}-SCPUE_{Tadj}$	Q	$FCPUE_S-FCPUE_T$, D, V	"	4.33	0.179	4.64	49.87

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$ $\ln(H)$, $\ln(D)$, V	all 2-factor and 3-factor	0.044	0.331	0.44	2.07
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.043	0.295	0.50	2.84
$\ln(S_S)-\ln(S_T)$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.041	0.407	0.18	1.94
$\ln(S_{Sadj})-\ln(S_{Tadj})$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.040	0.376	0.22	2.57
$\ln(S_S)-\ln(S_T)$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.043	0.372	0.29	1.88
$\ln(S_{Sadj})-\ln(S_{Tadj})$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$, $\ln(D)$, V	"	0.041	0.345	0.36	2.49
$\ln(SCPUE_S)-\ln(SCPUE_T)$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.045	0.305	0.35	2.33
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.044	0.269	0.43	3.13
$\ln(SCPUE_S)-\ln(SCPUE_T)$	R	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.043	0.358	0.17	1.79
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	R	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.042	0.325	0.25	2.47
$\ln(SCPUE_S)-\ln(SCPUE_T)$	Q	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.044	0.329	0.28	2.18
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	Q	$\ln(FCPUE_S)-\ln(FCPUE_T)$, $\ln(D)$, V	"	0.043	0.307	0.40	2.77

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
RS	T	RF, H, D, V	all 2-factor all 3-factor	0.037	0.279	0.63	2.74
RS_{adj}	T	RF, H, D, V	"	0.034	0.243	0.93	5.56
RS	R	RF, H, D, V	"	0.036	0.341	0.84	3.30
RS_{adj}	R	RF, H, D, V	"	0.032	0.313	1.02	5.19
RS	Q	RF, H, D, V	"	0.037	0.310	0.68	2.59
RS_{adj}	Q	RF, H, D, V	"	0.033	0.285	0.81	4.24
RSCPUE	T	RFCPUE, D, V	"	0.038	0.253	0.69	2.70
$RSCPUE_{adj}$	T	RFCPUE, D, V	"	0.034	0.222	0.96	5.50
RSCPUE	R	RFCPUE, D, V	"	0.038	0.280	0.80	2.81
$RSCPUE_{adj}$	R	RFCPUE, D, V	"	0.033	0.262	0.96	4.84
RSCPUE	Q	RFCPUE, D, V	"	0.038	0.273	0.67	2.57
$RSCPUE_{adj}$	Q	RFCPUE, D, V	"	0.033	0.259	0.78	3.99

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
LS	T	LF, H, D, V	all 2-factor all 3-factor	373.62	0.279	-0.63	2.74
LS_{adj}	T	LF, H, D, V	"	336.63	0.243	-0.93	5.56
LS	R	LF, H, D, V	"	358.58	0.341	-0.84	3.30
LS_{adj}	R	LF, H, D, V	"	321.17	0.313	-1.02	5.19
LS	Q	LF, H, D, V	"	369.45	0.310	-0.68	2.59
LS_{adj}	Q	LF, H, D, V	"	328.62	0.285	-0.81	4.24

Appendix I. Table 3 (cont).

B. Data paired by trip (41 observations, quad-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$S_S - S_T$	T	$F_S - F_T$, H	all 2-factor and 3-factor	3,358	0.584	1.28	2.73
$S_{Sadj} - S_{Tadj}$	T	$F_S - F_T$, H	"	3,777	0.447	1.37	1.70
$S_S - S_T$	R	$F_S - F_T$, H	"	2,058	0.838	1.60	5.09
$S_{Sadj} - S_{Tadj}$	R	$F_S - F_T$, H	"	3,150	0.706	1.00	2.73
$S_S - S_T$	Q	$F_S - F_T$, H	"	1,528	0.845	1.13	4.43
$S_{Sadj} - S_{Tadj}$	Q	$F_S - F_T$, H	"	2,956	0.646	1.31	3.02
$SCPUE_S - SCPUE_T$	T	$FCPUE_S - FCPUE_T$	all 2-factor	0.88	0.230	1.30	1.21
$SCPUE_{Sadj} - SCPUE_{Tadj}$	T	$FCPUE_S - FCPUE_T$	"	1.04	0.108	1.09	0.51
$SCPUE_S - SCPUE_T$	R	$FCPUE_S - FCPUE_T$	"	0.77	0.431	1.48	3.09
$SCPUE_{Sadj} - SCPUE_{Tadj}$	R	$FCPUE_S - FCPUE_T$	"	1.15	0.175	1.06	0.94
$SCPUE_S - SCPUE_T$	Q	$FCPUE_S - FCPUE_T$	"	0.78	0.386	1.16	1.60
$SCPUE_{Sadj} - SCPUE_{Tadj}$	Q	$FCPUE_S - FCPUE_T$	"	0.87	0.341	1.04	0.71

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	all 2-factor and 3-factor	0.018	0.555	0.82	0.52
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.017	0.471	0.18	-0.45
$\ln(S_S)-\ln(S_T)$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.015	0.757	0.94	1.06
$\ln(S_{Sadj})-\ln(S_{Tadj})$	R	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.014	0.717	0.35	0.97
$\ln(S_S)-\ln(S_T)$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.015	0.696	0.72	1.53
$\ln(S_{Sadj})-\ln(S_{Tadj})$	Q	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.011	0.717	0.11	-0.07
$\ln(SCPUE_S)-\ln(SCPUE_T)$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$	all 2-factor	0.022	0.372	1.05	1.07
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.024	0.177	0.73	0.74
$\ln(SCPUE_S)-\ln(SCPUE_T)$	R	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.017	0.608	0.93	2.75
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	R	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.022	0.363	0.68	1.67
$\ln(SCPUE_S)-\ln(SCPUE_T)$	Q	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.019	0.532	0.44	0.91
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	Q	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.017	0.466	-0.03	0.60

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Kurtosis coefficient
RS	T	RF, H	all 2-factor and 3-factor	0.014	0.491	-0.35	-0.07
RS_{adj}	T	RF, H	"	0.016	0.230	-0.07	-0.26
RS	R	RF, H	" "	0.012	0.724	-0.55	1.47
RS_{adj}	R	RF, H	"	0.016	0.528	-0.37	1.20
RS	Q	RF, H	"	0.013	0.618	-0.33	0.62
RS_{adj}	Q	RF, H	"	0.013	0.505	-0.01	0.09
RSCPUE	T	RFCPUE	all 2-factor	0.014	0.428	-0.67	0.32
$RSCPUE_{adj}$	T	RFCPUE	"	0.017	0.123	-0.35	0.04
RSCPUE	R	RFCPUE	"	0.010	0.646	-0.23	0.74
$RSCPUE_{adj}$	R	RFCPUE	"	0.015	0.333	-0.13	0.48
RSCPUE	Q	RFCPUE	"	0.012	0.562	-0.36	0.34
$RSCPUE_{adj}$	Q	RFCPUE	"	0.012	0.441	0.06	0.26

Appendix I. Table 3 (cont).

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b]	
						Skewness coefficient	Kurtosis coefficient
LS	T	LF, H	all 2-factor and 3-factor	141.8	0.491	0.35	-0.07
LS_{adj}	T	LF, H	"	164.7	0.230	0.07	-0.26
LS	R	LF, H	"	120.8	0.724	0.55	1.47
LS_{adj}	R	LF, H	"	158.7	0.528	0.37	1.20
LS	Q	LF, H	"	130.1	0.618	0.33	0.62
LS_{adj}	Q	LF, H	"	129.4	0.505	0.01	0.09

Appendix I. Table 3 (cont).

C. Data paired by tow (64 observations, twin-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Kurtosis coefficient
$S_S - S_T$	T	F_S-F_T, H, D, V	all 2-factor and 3-factor	124.3	0.420	-3.65	23.35
$S_{Sadj}-S_{Tadj}$	T	F_S-F_T, H, D, V	"	89.6	0.423	-3.32	21.00
$SCPUE_S-SCPUE_T$	T	$FCPUE_S-FCPUE_T$, D, V	"	28.39	0.209	-5.07	36.23
$SCPUE_{Sadj}-SCPUE_{Tadj}$	T	$FCPUE_S-FCPUE_T$, D, V	"	19.87	0.207	-4.65	33.69
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$ ln(H), ln(D), V	"	0.042	0.599	-2.36	8.46
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, ln(H), ln(D), V	"	0.027	0.650	-2.15	7.77
$\ln(SCPUE_S)-\ln(SCPUE_T)$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$, ln(D), V	"	0.048	0.410	-1.12	3.14
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$, ln(D), V	"	0.033	0.457	-0.44	2.74
RS	T	RF, H, D, V	"	0.067	0.464	2.79	12.31
RS_{adj}	T	RF, H, D, V	"	0.035	0.571	2.44	10.94
RSCPUE	T	RFCPUE, D, V	"	0.062	0.360	2.08	7.95
$RSCPUE_{adj}$	T	RFCPUE, D, V	"	0.034	0.457	1.04	5.21
LS	T	LF, H, D, V	"	672.1	0.464	-2.79	12.31
LS_{adj}	T	LF, H, D, V	"	346.3	0.571	-2.44	10.94

Appendix I. Table 3 (cont).

D. Data paired by trip (7 observations, twin-rigged trawlers)

Dependent variable	Classification variables	Continuous variables	Interactions	Variance[a], s^2	Coeff. of determ., r^2	Residuals[b] Skewness coefficient	Residuals[b] Kurtosis coefficient
$S_S - S_T$	T	F_S-F_T, H	None	4,016	0.333	-0.72	0.67
$S_{Sadj}-S_{Tadj}$	T	F_S-F_T, H	"	3,133	0.216	-0.99	0.69
$SCPUE_S-SCPUE_T$	T	$FCPUE_S-FCPUE_T$	"	4.82	0.267	-0.63	1.03
$SCPUE_{Sadj}-SCPUE_{Tadj}$	T	$FCPUE_S-FCPUE_T$	"	3.46	0.213	-0.80	0.53
$\ln(S_S)-\ln(S_T)$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.046	0.345	-0.35	-0.19
$\ln(S_{Sadj})-\ln(S_{Tadj})$	T	$\ln(F_S)-\ln(F_T)$, $\ln(H)$	"	0.042	0.162	-0.85	0.39
$\ln(SCPUE_S)-\ln(SCPUE_T)$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.040	0.252	-0.32	0.88
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	T	$\ln(FCPUE_S)-\ln(FCPUE_T)$	"	0.032	0.153	-0.92	0.84
RS	T	RF, H	"	0.056	0.308	0.70	0.66
RS_{adj}	T	RF, H	"	0.043	0.164	1.07	1.16
RSCPUE	T	RFCPUE	"	0.047	0.233	0.69	1.61
$RSCPUE_{adj}$	T	RFCPUE	"	0.033	0.153	1.15	1.68
LS	T	LF, H	"	563.8	0.308	-0.70	0.66
LS_{adj}	T	LF, H	"	431.8	0.164	-1.96	4.07

[a] Mean square residual.
[b] The mean of the residuals was zero in all GLM models shown in this table.

Appendix I. Table 4. Least squares means (LSMs) of selected dependent variables for various TED types, Regions and Seasons in General Linear Model (GLM) analyses of paired observations for TED-equipped and standard trawls. (see Appendix I text for description of symbols used for dependent and continuous variables).

A. Data paired by tow (706 observations, quad-rigged trawlers)

	TED-type		Region: Statistical subarea groupings					Season: Month groupings			
Dependent Variables	Georgia jumper	Georgia jumper, with funnel	18-21	13-17	9-12	1-8	>21	Dec-Feb	Mar-May	June-Aug	Sept-Nov
S_S-S_T	3.92	2.59	4.35ns[a]	4.36	2.83ns	-1.37ns	1.07ns	-1.02ns	-2.57ns	2.05	2.20ns
$S_{Sadj}-S_{Tadj}$	7.48	3.48	8.16	4.44	4.56	-1.02ns	4.01ns	0.28ns	-2.54ns	4.71	3.16ns
$SCPUE_S-SCPUE_T$	1.56	0.70	0.92ns	0.52ns	0.47ns	1.16ns	0.89ns	0.03ns	1.14	0.88	0.76
$SCPUE_{Sadj}-SCPUE_{Tadj}$	2.04	0.92	2.27	0.60	0.78	1.00ns	1.56ns	0.26ns	1.00ns	1.51	0.73ns
$\ln(S_S)-\ln(S_T)$	0.09ns	0.16	0.18ns	0.24	0.16	0.02ns	0.01ns	0.03ns	0.18ns	0.11	0.11ns
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.14	0.18	0.32	0.22	0.12ns	-0.03ns	0.08ns	0.11	0.09ns	0.16	0.13ns
$\ln(SCPUE_S)-\ln(SCPUE_T)$	0.15	0.13	0.24	0.14	0.08ns	0.10ns	-0.01ns	0.05ns	0.18	0.11	0.12
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	0.18	0.16	0.41	0.15	0.10ns	0.08ns	0.01ns	0.11ns	0.16	0.16	0.11
RS	0.94	0.88	0.82	0.81	0.89	0.98	1.12	1.01	0.91	0.93	0.93
RS_{adj}	0.87	0.86	0.71	0.81	0.90	0.98	1.08	0.96	0.96	0.88	0.93
RSCPUE	0.89	0.92	0.82	0.90	0.97	0.93	1.12	1.01	0.92	0.93	0.93
$RSCPUE_{adj}$	0.85	0.88	0.69	0.87	0.94	0.95	1.09	0.95	0.95	0.87	0.93

Appendix I. Table 4 (cont).

Dependent Variables	TED-type		Region: Statistical subarea groupings					Season: Month groupings			
	Georgia jumper	Georgia jumper, with funnel	18-21	13-17	9-12	1-8	>21	Dec-Feb	Mar-May	June-Aug	Sept-Nov
LS	6.38ns	11.83	18.22	19.07	10.55	1.58ns	-11.72ns	-1.30ns	9.34ns	6.93	6.81ns
LS_{adj}	13.05	14.20	29.19	19.39	10.28	2.12ns	-7.86ns	4.38ns	4.25ns	12.20	7.49ns

Appendix I. Table 4 (cont).

B. Data paired by trip (41 observations, quad-rigged trawlers)

Dependent Variables	TED-type: Georgia jumper	TED-type: Georgia jumper, with funnel	Region (Statistical subarea groupings): 18-21	13-17	9-12	1-8	>21	Season (Month groupings): Dec-Feb	Mar-May	June-Aug	Sept-Nov
S_S-S_T	38.9ns	31.9	29.7ns	32.3ns	22.8ns	58.6ns	48.1ns	9.2ns	-46.3ns	30.8	NE[b]
$S_{Sadj}-S_{Tadj}$	59.0ns	52.2	68.4	97.8ns	-32.1ns	43.8ns	66.6ns	27.8ns	-60.3ns	71.0	NE
$SCPUE_S-SCPUE_T$	0.91	0.49	0.50ns	0.96ns	0.57ns	0.06ns	0.86	0.03ns	1.20ns	0.71	0.43ns
$SCPUE_{Sadj}-SCPUE_{Tadj}$	1.20	0.79	1.02	1.01ns	0.53ns	0.24ns	1.11	0.17ns	0.08ns	1.22	0.34ns
$\ln(S_S)-\ln(S_T)$	0.09	0.11	0.11	0.57	-0.07ns	-0.07ns	0.03ns	0.03ns	0.08ns	0.14	NE
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.14	0.15	0.13	0.44	-0.34ns	-0.12ns	0.06ns	0.03ns	-0.05ns	0.19	NE
$\ln(SCPUE_S)-\ln(SCPUE_T)$	0.15	0.11	0.10	0.36	0.11ns	-0.01ns	0.12	0.02ns	0.24	0.14	0.10ns
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	0.19	0.15	0.20	0.30	0.05ns	0.02ns	0.17	0.07ns	0.06ns	0.19	0.07ns
RS	0.95	0.90	0.89	0.71	1.01	0.95	1.10	0.96	0.82	0.89	NE
RS_{adj}	0.90	0.87	0.86	0.74	1.11	0.99	1.11	0.93	0.91	0.84	NE
RSCPUE	0.88	0.91	0.91	0.75	0.93	0.92	0.91	0.98	0.81	0.89	0.94
$RSCPUE_{adj}$	0.84	0.87	0.82	0.77	0.96	0.91	0.87	0.94	0.90	0.84	0.96
LS	4.62ns	9.60	10.81	28.64	-0.65ns	4.86ns	-9.56ns	3.90ns	18.09	11.13	NE
LS_{adj}	9.99ns	13.12	13.60	26.18	-11.09ns	1.06ns	-10.93ns	6.66ns	8.65ns	15.88	NE

Appendix I. Table 4 (cont).

C. Data paired by tow (64 observations, twin-rigged trawlers)

Dependent Variables	TED-type: Georgia jumper	TED-type: Georgia jumper, with funnel	Region (Statistical subarea groupings): 18-21	13-17	9-12	1-8	>21	Season (Month groupings): Dec-Feb	Mar-May	June-Aug	Sept-Nov
$S_S - S_T$	1.42ns	11.32ns									
$S_{Sadj} - S_{Tadj}$	3.01ns	12.35ns									
$SCPUE_S - SCPUE_T$	0.55ns	-0.11ns									
$SCPUE_{Sadj} - SCPUE_{Tadj}$	0.92ns	0.42ns									
$\ln(S_S) - \ln(S_T)$	0.11ns	0.21ns									
$\ln(S_{Sadj}) - \ln(S_{Tadj})$	0.24	0.22ns									
$\ln(SCPUE_S) - \ln(SCPUE_T)$	0.17	0.00ns									
$\ln(SCPUE_{Sadj}) - \ln(SCPUE_{Tadj})$	0.20	0.05ns									
RS	0.92	0.69									
RS_{adj}	0.85	0.65									
RSCPUE	0.87	1.01									
$RSCPUE_{adj}$	0.86	0.94									
LS	7.94ns	31.30ns									
LS_{adj}	15.43	34.59									

Appendix I. Table 4 (cont).

D. Data paired by trip (7 observations, twin-rigged trawlers)

Dependent Variables	TED-type: Georgia jumper	TED-type: Georgia jumper, with funnel	Region: Statistical subarea groupings: 18-21	13-17	9-12	1-8	>21	Season: Month groupings: Dec-Feb	Mar-May	June-Aug	Sept-Nov
S_S-S_T	14.88ns	-3.71ns									
$S_{Sadj}-S_{Tadj}$	23.11ns	4.84ns									
$SCPUE_S-SCPUE_T$	0.69ns	-0.59ns									
$SCPUE_{Sadj}-SCPUE_{Tadj}$	0.87ns	-0.11ns									
$\ln(S_S)-\ln(S_T)$	0.11ns	0.04ns									
$\ln(S_{Sadj})-\ln(S_{Tadj})$	0.15ns	-0.06ns									
$\ln(SCPUE_S)-\ln(SCPUE_T)$	0.14ns	0.02ns									
$\ln(SCPUE_{Sadj})-\ln(SCPUE_{Tadj})$	0.16ns	0.05ns									
RS	0.90	0.99									
RS_{adj}	0.86	0.96									
RSCPUE	0.87	1.01									
$RSCPUE_{adj}$	0.85	0.97									

Appendix I. Table 4 (cont).

	TED-type		Region					Season			
			Statistical subarea groupings					Month groupings			
Dependent Variables	Georgia jumper	Georgia jumper, with funnel	18-21	13-17	9-12	1-8	>21	Dec-Feb	Mar-May	June-Aug	Sept-Nov
LS	9.88ns	1.40ns									
LS_{adj}	13.71ns	4.11ns									

[a] ns indicates that the LSM is not significantly different from the zero at $P \leq 0.05$; otherwise the LSM is significantly different from zero.
[b] NE indicates that the LSM was not estimable because of data imbalance (insufficient sample size).

APPENDIX II

APPENDIX TABLES

Appendix II. Table 1. Summary of operation codes for trawl performance.

A = Nets not spread; typically doors are flipped or doors hung together so net could not spread.
B = Gear bogged; the net has picked up a quantity of sand or mud such that the net can not be easily towed.
C = Bag choked; the catch in the net is prevented from getting into the bag by something (grass, sticks, turtle, etc.) clogging net or by the twisting of the lazy-line.
D = Gear not digging; the net is fishing off the bottom due to insufficient weight.
E = Twisted warp or line; the cables composing the bridle get twisted (from passing over blocks which occasionally must be removed before continuing to fish). Use this code if catch was affected.
F = Gear fouled; the gear has become entangled in itself. Typically this involves the webbing and some object like a float or chains.
G = Bag untied; bag of net not tied when dragging net.
H = Rough weather; if the weather is so bad fishing is stopped, then the previous tow should receive this code if the rough conditions affected the catch.
I = Torn webbing or lost net; usually results from hanging the net and tearing it loose. The net comes back with large tears if at all. Do not use this code if there are only a few broken meshes. Continue using this code until net is repaired or replaced.
J = Dumped catch; tow was made but catch was discarded, perhaps because of too much trash, fish, sponge. Give reason in Comments.
K = No pick up; tow made but net not dumped on deck because nets are brought up, boat changes location and nets are towed more before decking.
L = Hung up; untimely termination of a tow by a hang. Specify trawl(s) which were hung and caused lost time in Comments.
M = Bags dumped together and catches not separated.
N = Net did not fish; no apparent cause.
O = Gear fouled on object; typically a log caught in bag or TED. Net may be towed but performance is affected. Give specifics in Comments.
P = No measurement taken of shrimp or total catch.
Q = Cable breaks and net lost. Describe in Comments.
R = Net caught in wheel.
S = Tickler chain fouled or tangled.
T = Other Problems
U = TED's tied shut.
Z = Successful tow

Appendix II. Table 2. Frequency of Operation Codes For Standard Net, Georgia TED without funnel, and Georgia TED with a Funnel.

Operation Code	Standard Net Freq.	%	Georgia TED w/o funnel Freq.	%	Georgia TED w/funnel Freq.	%
A	2	0.1	0	0.0	0	0.0
AF	0	0.0	0	0.0	2	0.2
B	11	0.5	2	0.3	10	1.0
BF	4	0.2	0	0.0	2	0.2
BM	2	0.1	1	0.2	5	0.5
BR	2	0.1	0	0.0	1	0.1
C	2	0.1	3	0.5	5	0.5
CF	0	0.0	1	0.2	0	0.0
CM	0	0.0	0	0.0	1	0.1
E	1	0.1	0	0.0	0	0.0
EB	0	0.0	0	0.0	1	0.1
F	21	1.0	31	5.1	13	1.3
FC	0	0.0	0	0.0	1	0.1
FM	4	0.2	0	0.0	0	0.0
G*	7	0.3	0	0.0	0	0.0
I*	25	1.2	3	0.5	13	1.3
IB	3	0.2	0	0.0	0	0.0
IF	1	0.1	0	0.0	0	0.0
IM*	0	0.0	0	0.0	1	0.1
J*	7	0.3	0	0.0	7	0.7
JM*	4	0.2	0	0.0	4	0.4
JP*	0	0.0	1	0.2	0	0.0
K*	80	3.9	20	3.3	4	0.4
KP*	1	0.1	0	0.0	1	0.1
L*	3	0.2	0	0.0	2	0.2
LI*	1	0.1	0	0.0	1	0.1
LM*	1	0.1	0	0.0	1	0.1
LS	1	0.1	0	0.0	0	0.0
M*	113	5.6	16	2.6	49	4.9
MF	2	0.1	1	0.2	0	0.0
MI*	3	0.2	1	0.2	0	0.0
MO	2	0.1	0	0.0	2	0.2
MP*	38	1.9	9	1.5	14	1.4
N	0	0.0	0	0.0	3	0.3
O	14	0.7	1	0.2	27	2.7
OI	0	0.0	0	0.0	1	0.1
OS	1	0.1	1	0.2	0	0.0
P*	20	1.0	1	0.2	13	1.3
PF	1	0.1	0	0.0	1	0.1
PM*	2	0.1	0	0.0	2	0.2
Q*	0	0.0	0	0.0	1	0.1
S	43	2.1	13	2.1	26	2.6
T	1	0.5	0	0.0	0	0.0
U*	0	0.0	2	0.3	4	0.4
UI*	0	0.0	0	0.0	0	0.0
UO	0	0.0	0	0.0	1	0.1
Z*	1599	78.7	500	82.4	783	78.1

*These operational codes reflect tows with no gear related problems attributal to TEDs.

Appendix II. Table 3. Frequency of Operation Codes For Standard Net, Morrison TED, Saunder's TED, and Golden TED.

Operation	Standard Net		Morrison TED		Saunder's TED		Golden TED	
Code	Freq.	%	Freq.	%	Freq.	%	Freq.	%
A	2	0.1	0	0.0	0	0.0	0	0.0
AF	0	0.0	0	0.0	0	0.0	0	0.0
B	11	0.5	0	0.0	1	1.1	0	0.0
BF	4	0.2	0	0.0	0	0.0	0	0.0
BM	2	0.1	0	0.0	0	0.0	0	0.0
BR	2	0.1	0	0.0	1	1.1	0	0.0
C	2	0.1	2	2.9	0	0.0	0	0.0
CF	0	0.0	0	0.0	0	0.0	0	0.0
CM	0	0.0	0	0.0	0	0.0	0	0.0
E	1	0.1	0	0.0	0	0.0	0	0.0
EB	0	0.0	0	0.0	0	0.0	0	0.0
F	21	1.0	1	1.5	1	1.1	0	0.0
FC	0	0.0	0	0.0	0	0.0	0	0.0
FM	4	0.2	0	0.0	0	0.0	0	0.0
G*	7	0.3	0	0.0	0	0.0	0	0.0
I*	25	1.2	0	0.0	1	1.1	0	0.0
IB	3	0.2	0	0.0	0	0.0	0	0.0
IF	1	0.1	0	0.0	0	0.0	0	0.0
IM*	0	0.0	0	0.0	0	0.0	0	0.0
J*	7	0.3	0	0.0	0	0.0	0	0.0
JM*	4	0.2	0	0.0	0	0.0	0	0.0
JP*	0	0.0	0	0.0	0	0.0	0	0.0
K*	80	3.9	28	41.2	0	0.0	0	0.0
KP*	1	0.1	0	0.0	0	0.0	0	0.0
L*	3	0.2	0	0.0	0	0.0	0	0.0
LI*	1	0.1	0	0.0	0	0.0	0	0.0
LM*	1	0.1	0	0.0	0	0.0	0	0.0
LS	1	0.1	0	0.0	0	0.0	0	0.0
M*	113	5.6	9	13.2	1	1.1	8	100.0
MF	2	0.1	0	0.0	0	0.0	0	0.0
MI*	3	0.2	0	0.0	0	0.0	0	0.0
MO	2	0.1	0	0.0	0	0.0	0	0.0
MP*	38	1.9	6	8.8	0	0.0	0	0.0
N	0	0.0	0	0.0	0	0.0	0	0.0
O	14	0.7	0	0.0	9	9.9	0	0.0
OI	0	0.0	0	0.0	0	0.0	0	0.0
OS	1	0.1	0	0.0	0	0.0	0	0.0
P*	20	1.0	0	0.0	0	0.0	0	0.0
PF	1	0.1	0	0.0	0	0.0	0	0.0
PM*	2	0.1	0	0.0	0	0.0	0	0.0
Q*	0	0.0	0	0.0	0	0.0	0	0.0
S	43	2.1	0	0.0	2	2.2	0	0.0
T	11	0.5	0	0.0	0	0.0	0	0.0
U*	0	0.0	0	0.0	1	1.1	0	0.0
UI*	0	0.0	0	0.0	1	1.1	0	0.0
UO	0	0.0	0	0.0	2	2.2	0	0.0
Z*	1599	8.7	22	32.47	1	78.1	0	0.0

*These operational codes reflect tows with no gear related problems attributal to TEDs.

Appendix II. Table 4. Summary of Regression Analyses on Twin-Rigged Vessels: TED-equipped vs Standard Shrimp Nets. By area and season; data paired by tow.

Class	Dependent Variable	Independ. Variable	Sample Size	Slope	Intercept	Variance From Regression	R^2	Regression Equation
GT/NF	TEDCPUSH	STDCPUSH	28	0.976[a]	-0.526	0.904	0.896	Y = -0.526 + 0.976X
GT/NF	TEDSH	STDSH	28	0.844	0.317	14.108	0.871	Y = 0.317 + 0.844X
GT/NF	TEDCPUTR	STDCPUTR	28	0.870	0.022	0.888	0.892	Y = 0.022 + 0.870X
GT/NF	TEDSHTR	STDSHTR	28	0.785	1.441	12.470	0.886	Y = 1.441 + 0.785X
GT/NF	TEDFI	STDFI	28	0.715	14.908	489.299	0.583	Y = 14.908 + 0.715X
GT/WF	TEDCPUSH	STDCPUSH	36	1.658	-5.106	29.794	0.803	Y = -5.106 + 1.658X
GT/WF	TEDSH	STDSH	36	1.221	-3.713	194.656	0.747	Y = -3.713 + 1.221X
GT/WF	TEDCPUTR	STDCPUTR	36	1.486	-4.461	20.052	0.867	Y = -4.461 + 1.486X
GT/WF	TEDSHTR	STDSHTR	36	1.205	-5.000	132.120	0.828	Y = -5.000 + 1.205X
GT/WF	TEDFI	STDFI	36	1.027	-2.486	2714.196	0.505	Y = -2.486 + 1.027X
TEXAS	TEDCPUSH	STDCPUSH	64	1.563	-4.074	18.195	0.809	Y = -4.074 + 1.563X
TEXAS	TEDSH	STDSH	64	1.163	-3.969	123.674	0.754	Y = -3.969 + 1.163X
TEXAS	TEDCPUTR	STDCPUTR	64	1.406	-3.474	12.841	0.864	Y = -3.474 + 1.406X
TEXAS	TEDSHTR	STDSHTR	64	1.130	-4.258	89.669	0.821	Y = -4.258 + 1.130X
TEXAS	TEDFI	STDFI	64	0.936[a]	3.719	1737.034	0.513	Y = 3.719 + 0.936X
WINTER	TEDCPUSH	STDCPUSH	5	1.017	-0.633	2.160	0.876	Y = -0.633 + 1.017X
WINTER	TEDSH	STDSH	5	0.886[a]	-0.138	34.871	0.877	Y = -1.380 + 0.886X
WINTER	TEDCPUTR	STDCPUTR	5	0.881[a]	-0.476	1.729	0.901	Y = -0.476 + 0.881X
WINTER	TEDSHTR	STDSHTR	5	0.811[a]	-0.546	39.014	0.863	Y = -0.546 + 0.811X
WINTER	TEDFI	STDFI	5	1.252[a]	-8.912	78.441	0.605	Y = -8.912 + 1.252X
FALL	TEDCPUSH	STDCPUSH	59	1.579	-4.168	19.331	0.811	Y = -4.168 + 1.579X
FALL	TEDSH	STDSH	59	1.197	-4.353	128.470	0.756	Y = -4.353 + 1.197X
FALL	TEDCPUTR	STDCPUTR	59	1.422	-3.510	13.329	0.869	Y = -3.510 + 1.422X
FALL	TEDSHTR	STDSHTR	59	1.176	-4.782	87.021	0.834	Y = -4.782 + 1.176X
FALL	TEDFI	STDFI	59	0.933[a]	4.109	1883.932	0.507	Y = 4.109 + 0.933X

GT/NF = GEORGIA TED WITHOUT A FUNNEL
GT/WF = GEORGIA TED WITH A FUNNEL
TEDCPUSH = CPUE OF SHRIMP IN TED NET NOT ADJUSTED FOR TRY NET
STDCPUSH = CPUE OF SHRIMP IN STANDARD NET NOT ADJUSTED FOR TRY NET
TEDSH = CATCH OF SHRIMP IN TED NET NOT ADJUSTED FOR TRY NET
STDSH = CATCH OF SHRIMP IN STANDARD NET NOT ADJUSTED FOR TRY NET
TEDCPUTR = CPUE OF SHRIMP IN TED NET ADJUSTED FOR TRY NET

STDCPUTR = CPUE OF SHRIMP IN STANDARD NET ADJUSTED FOR TRY NET
TEDSHTR = CATCH OF SHRIMP IN TED NET ADJUSTED FOR TRY NET
STDSHTR = CATCH OF SHRIMP IN STANDARD NET ADJUSTED FOR TRY NET
TEDFI = CATCH OF FISH IN TED NET NOT ADJUSTED FOR TRY NET
STDFI = CATCH OF FISH IN STANDARD NET NOT ADJUSTED FOR TRY NET

[a] These slopes are not significantly different from 1.

Appendix II. Table 5. Summary of Regression Analyses on Quad-Rigged Vessels: TED-equipped vs Standard Shrimp Nets. By area and season; data paired by tow.

Class	Dependent Variable	Independ. Variable	Sample Size	Slope	Intercept	Variance From Regression	R^2	Regression Equation
GT/NF	TEDCPUSH	STDCPUSH	256	0.704	1.086	3.768	0.846	Y = 1.086 + 0.704X
GT/NF	TEDSH	STDSH	256	0.837	0.933	30.420	0.891	Y = 0.933 + 0.837X
GT/NF	TEDCPUTR	STDCPUTR	256	0.666	1.136	3.748	0.847	Y = 1.136 + 0.666X
GT/NF	TEDSHTR	STDSHTR	256	0.781	1.207	28.378	0.899	Y = 1.207 + 0.781X
GT/NF	TEDFI	STDFI	256	0.711	28.233	7346.102	0.525	Y = 28.233 + 0.711X
GT/WF	TEDCPUSH	STDCPUSH	450	0.867	0.366	2.032	0.927	Y = 0.366 + 0.867X
GT/WF	TEDSH	STDSH	450	0.868	2.062	49.279	0.911	Y = 2.062 + 0.868X
GT/WF	TEDCPUTR	STDCPUTR	450	0.843	0.322	1.836	0.936	Y = 0.322 + 0.843X
GT/WF	TEDSHTR	STDSHTR	450	0.868	1.127	43.716	0.925	Y = 1.127 + 0.868X
GT/WF	TEDFI	STDFI	450	0.926	6.271	47218.721	0.722	Y = 6.271 + 0.926X
TEXAS	TEDCPUSH	STDCPUSH	112	0.908	0.281	2.204	0.935	Y = 0.281 + 0.908X
TEXAS	TEDSH	STDSH	112	0.919	1.120	48.473	0.902	Y = 1.120 + 0.919X
TEXAS	TEDCPUTR	STDCPUTR	112	0.825	0.351	2.334	0.931	Y = 0.351 + 0.825X
TEXAS	TEDSHTR	STDSHTR	112	0.847	1.180	51.487	0.895	Y = 1.180 + 0.847X
TEXAS	TEDFI	STDFI	112	0.531	57.065	20153.211	0.390	Y = 57.065 + 0.531X
LA	TEDCPUSH	STDCPUSH	154	0.944	-0.114	1.291	0.917	Y = -0.114 + 0.944X
LA	TEDSH	STDSH	154	1.006[a]	-1.450	30.821	0.931	Y = -1.450 + 1.006X
LA	TEDCPUTR	STDCPUTR	154	0.906	-0.059	1.010	0.936	Y = -0.059 + 0.906X
LA	TEDSHTR	STDSHTR	154	0.955	-1.066	25.273	0.944	Y = -1.066 + 0.955X
LA	TEDFI	STDFI	154	1.047[a]	-14.200	90296.187	0.701	Y = 14.200 + 1.047X
MS/AL/PN	TEDCPUSH	STDCPUSH	88	0.834	0.872	2.470	0.921	Y = 0.872 + 0.834X
MS/AL/PN	TEDSH	STDSH	88	0.842	5.174	62.986	0.936	Y = 5.174 + 0.842X
MS/AL/PN	TEDCPUTR	STDCPUTR	88	0.840	0.622	1.826	0.945	Y = 0.622 + 0.840X
MS/AL/PN	TEDSHTR	STDSHTR	88	0.877	2.614	51.816	0.953	Y = 2.614 + 0.877X
MS/AL/PN	TEDFI	STDFI	88	0.770	70.496	21916.602	0.774	Y = 70.496 + 0.770X
WFL	TEDCPUSH	STDCPUSH	106	0.722	0.792	2.105	0.846	Y = 0.792 + 0.722X
WFL	TEDSH	STDSH	106	0.653	4.524	30.547	0.854	Y = 4.524 + 0.653X
WFL	TEDCPUTR	STDCPUTR	106	0.761	0.545	2.040	0.862	Y = 0.545 + 0.761X
WFL	TEDSHTR	STDSHTR	106	0.694	3.581	30.266	0.868	Y = 3.581 + 0.694X
WFL	TEDFI	STDFI	106	0.747	23.913	8807.325	0.805	Y = 23.913 + 0.747X
ATL	TEDCPUSH	STDCPUSH	246	0.733	0.995	3.930	0.875	Y = 0.995 + 0.733X
ATL	TEDSH	STDSH	246	0.783	1.767	25.502	0.890	Y = 1.767 + 0.783X
ATL	TEDCPUTR	STDCPUTR	246	0.697	1.078	4.303	0.863	Y = 1.078 + 0.697X
ATL	TEDSHTR	STDSHTR	246	0.749	1.891	28.042	0.879	Y = 1.891 + 0.749X
ATL	TEDFI	STDFI	246	0.497	59.377	5329.824	0.469	Y = 59.377 + 0.497X
WINTER	TEDCPUSH	STDCPUSH	142	0.914	0.421	1.013	0.828	Y = 0.421 + 0.914X
WINTER	TEDSH	STDSH	142	1.086	-0.543	12.337	0.906	Y = -0.543 + 1.086X
WINTER	TEDCPUTR	STDCPUTR	142	0.874	0.385	0.915	0.844	Y = 0.385 + 0.874X
WINTER	TEDSHTR	STDSHTR	142	1.027[a]	-0.608	11.571	0.912	Y = -0.608 + 1.027X
WINTER	TEDFI	STDFI	142	1.141	-19.631	17406.958	0.693	Y = -19.631 + 1.141X

Appendix II. Table 5 (continued). Summary of Regression Analyses on Quad-Rigged Vessels: TED vs Standard Shrimp Nets. By area and season; data paired by tow.

Class	Dependent Variable	Independ. Variable	Sample Size	Slope	Intercept	Variance From Regression	R^2	Regression Equation
SPRING	TEDCPUSH	STDCPUSH	148	0.730	0.574	1.411	0.879	Y = 0.574 + 0.730X
SPRING	TEDSH	STDSH	148	0.673	3.597	23.154	0.868	Y = 3.597 + 0.673X
SPRING	TEDCPUTR	STDCPUTR	148	0.766	0.433	1.511	0.880	Y = 0.433 + 0.766X
SPRING	TEDSHTR	STDSHTR	148	0.711	2.873	23.766	0.876	Y = 2.873 + 0.711X
SPRING	TEDFI	STDFI	148	0.959[a]	11.623	47726.106	0.751	Y = 11.623 + 0.959X
SUMMER	TEDCPUSH	STDCPUSH	340	0.795	0.795	4.473	0.874	Y = 0.795 + 0.795X
SUMMER	TEDSH	STDSH	340	0.907	0.172	51.411	0.896	Y = 0.172 + 0.907X
SUMMER	TEDCPUTR	STDCPUTR	340	0.747	0.833	4.375	0.876	Y = 0.833 + 0.747X
SUMMER	TEDSHTR	STDSHTR	340	0.836	0.651	47.920	0.903	Y = 0.651 + 0.836X
SUMMER	TEDFI	STDFI	340	0.549	59.020	15195.295	0.515	Y = 59.020 + 0.549X
FALL	TEDCPUSH	STDCPUSH	76	0.822	0.505	1.865	0.939	Y = 0.505 + 0.822X
FALL	TEDSH	STDSH	76	0.866	1.624	58.951	0.951	Y = 1.624 + 0.866X
FALL	TEDCPUTR	STDCPUTR	76	0.864	0.285	1.723	0.948	Y = 0.285 + 0.864X
FALL	TEDSHTR	STDSHTR	76	0.925	-0.481	49.733	0.964	Y = 0.481 + 0.925X
FALL	TEDFI	STDFI	76	1.149	-129.522	61072.201	0.845	Y = -129.522 + 1.149X

GT/NF = GEORGIA TED WITHOUT A FUNNEL
GT/WF = GEORGIA TED WITH A FUNNEL
TEDCPUSH = CPUE OF SHRIMP IN TED NET NOT ADJUSTED FOR TRY NET
STDCPUSH = CPUE OF SHRIMP IN STANDARD NET NOT ADJUSTED FOR TRY NET
TEDSH = CATCH OF SHRIMP IN TED NET NOT ADJUSTED FOR TRY NET
STDSH = CATCH OF SHRIMP IN STANDARD NET NOT ADJUSTED FOR TRY NET
TEDCPUTR = CPUE OF SHRIMP IN TED NET ADJUSTED FOR TRY NET
STDCPUTR = CPUE OF SHRIMP IN STANDARD NET ADJUSTED FOR TRY NET
TEDSHTR = CATCH OF SHRIMP IN TED NET ADJUSTED FOR TRY NET
STDSHTR = CATCH OF SHRIMP IN STANDARD NET ADJUSTED FOR TRY NET
TEDFI = CATCH OF FISH IN TED NET NOT ADJUSTED FOR TRY NET
STDFI = CATCH OF FISH IN STANDARD NET NOT ADJUSTED FOR TRY NET

[a] These slopes are not significantly different from 1.

APPENDIX III

APPENDIX FIGURES

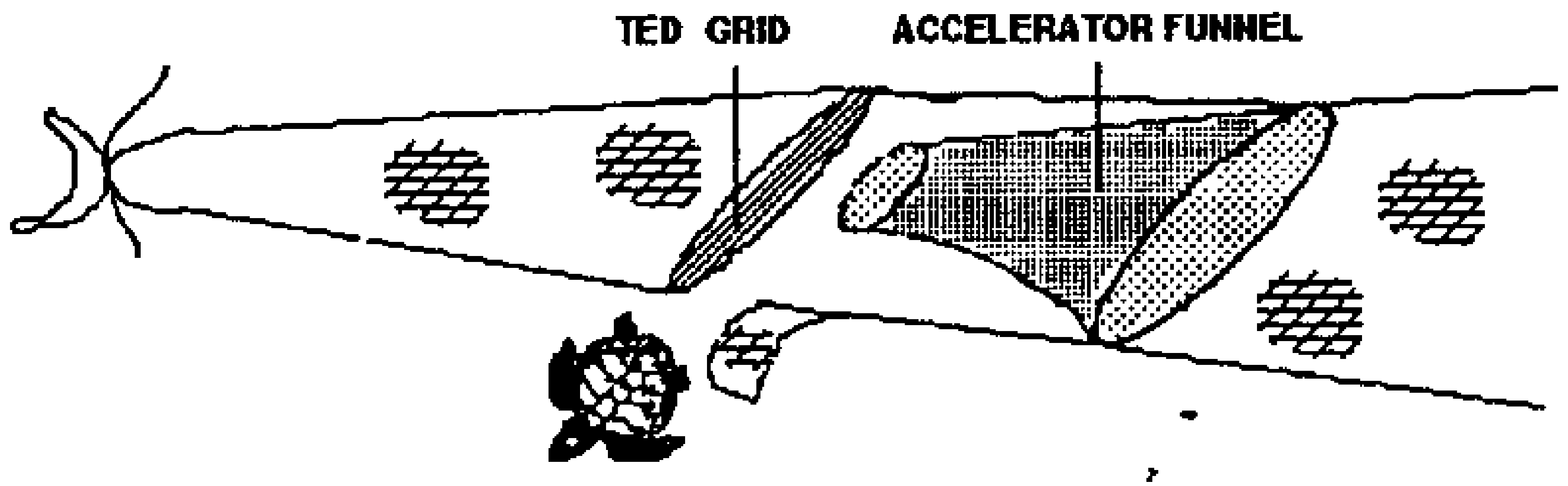


Figure 1. Schematic diagram of the end of a shrimp trawl containing a Georgia TED and an accelerator funnel.

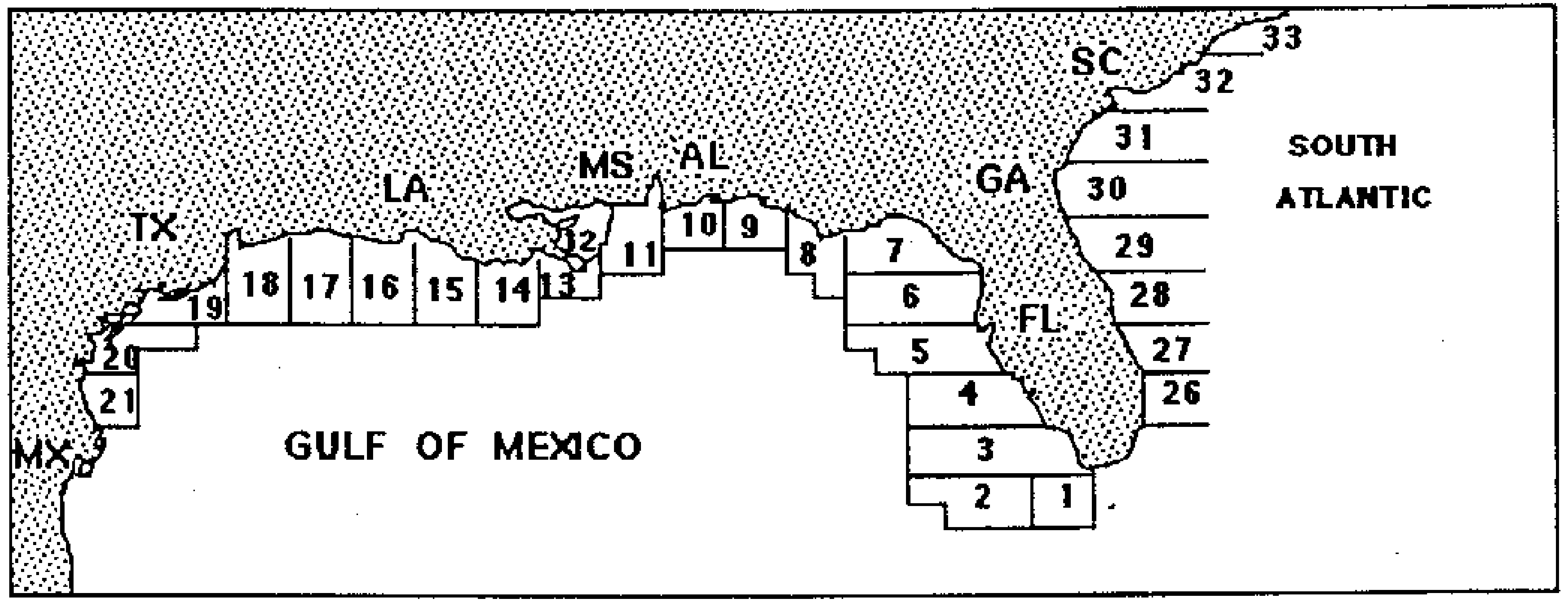


Figure 2. NMFS statistical areas in the Gulf of Mexico and south Atlantic.

FIGURE 3. STANDARD SHRIMP CATCH VS STANDARD FISH CATCH, NOT ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED N = 770

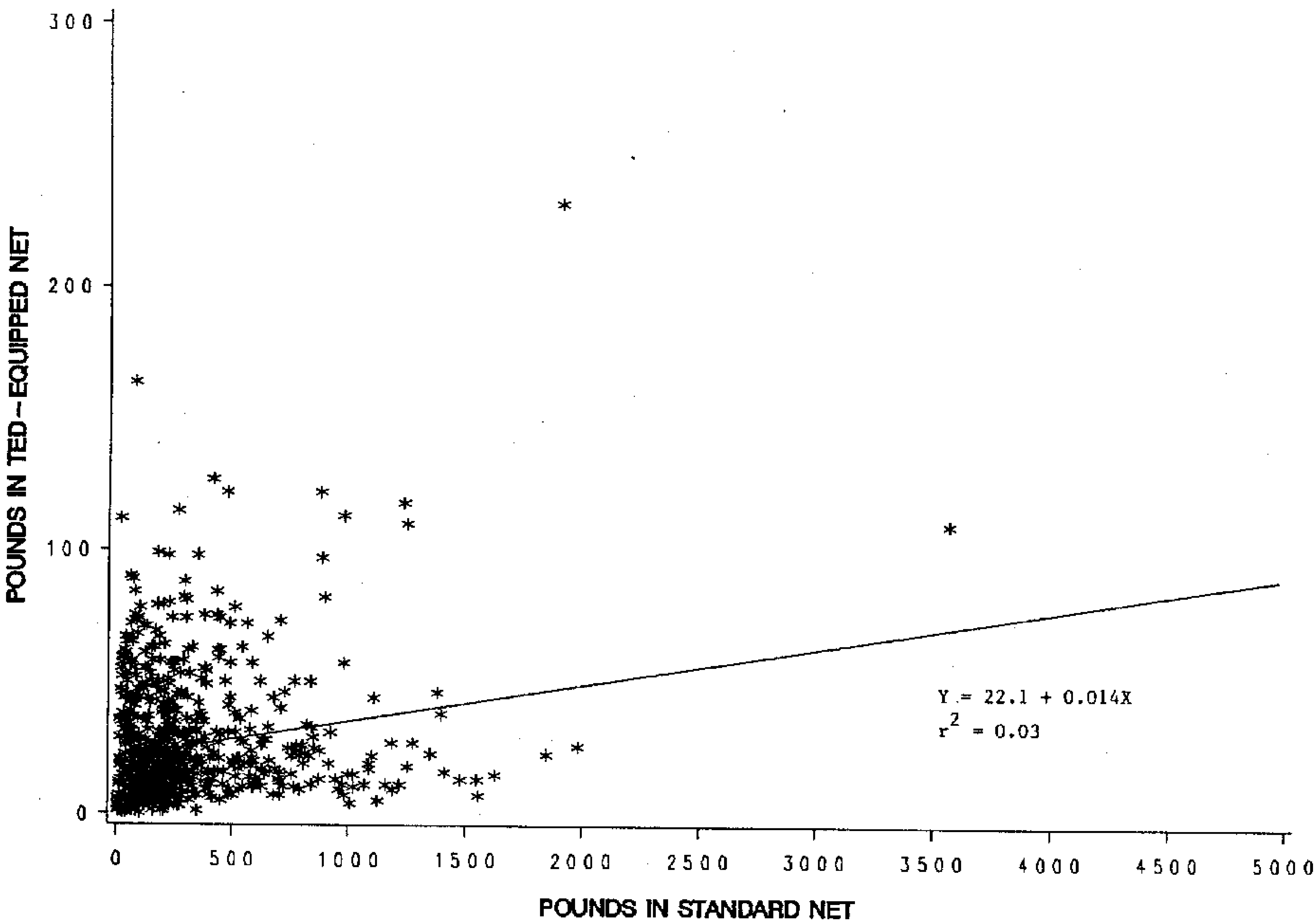


FIGURE 4. STANDARD SHRIMP CATCH VS STANDARD FISH CATCH, ADJUSTED FOR TRY NET CATCH, ALL AREAS/VESSELS COMBINED N = 770

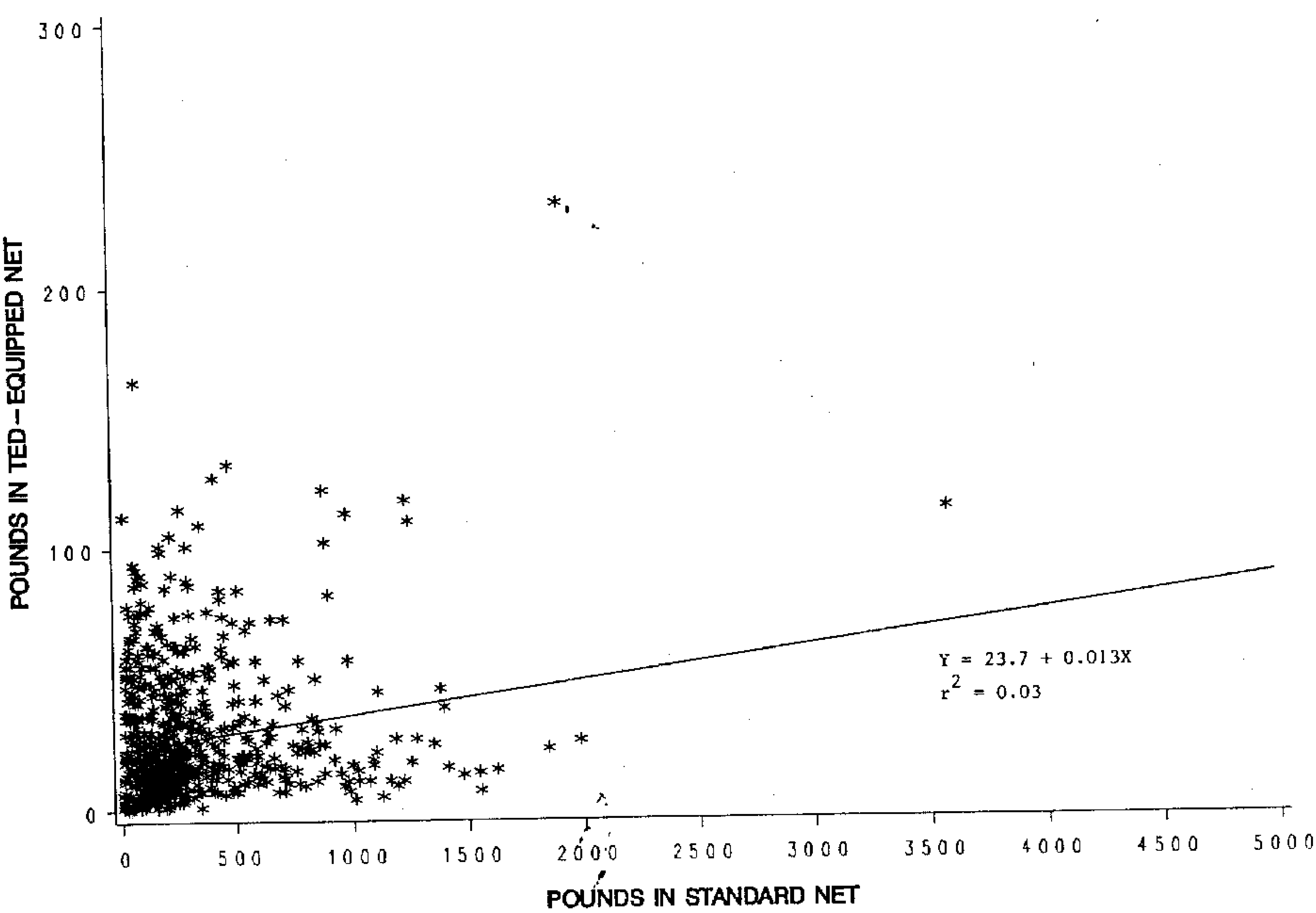


FIGURE 5. TED SHRIMP CATCH VS TED FISH CATCH,
NOT ADJUSTED FOR TRY NET CATCH,
ALL AREAS/VESSELS COMBINED
N = 770

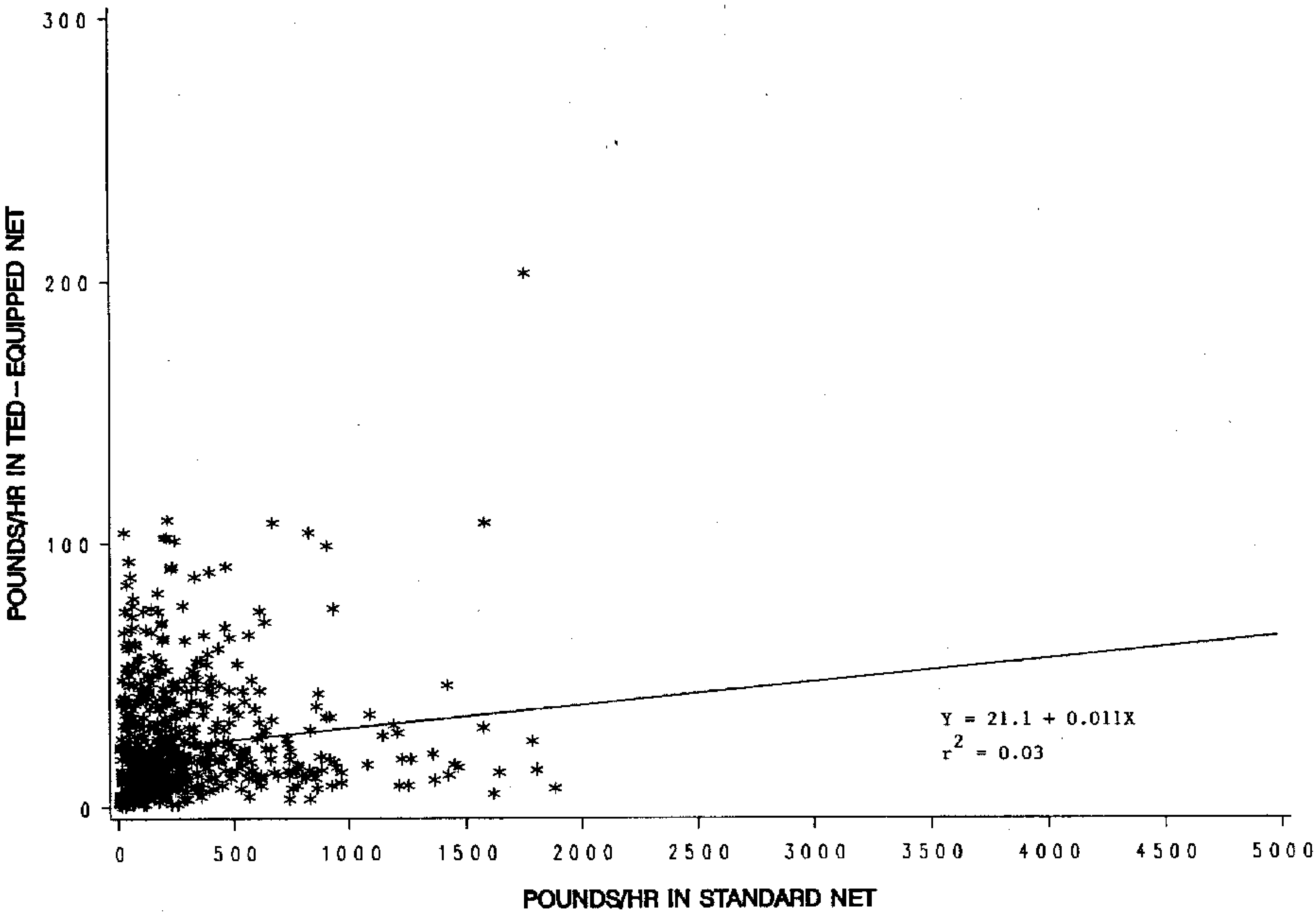


FIGURE 6. TED SHRIMP CATCH VS FISH CATCH
ADJUSTED FOR TRY NET CATCH,
ALL AREAS/VESSELS COMBINED
N = 770

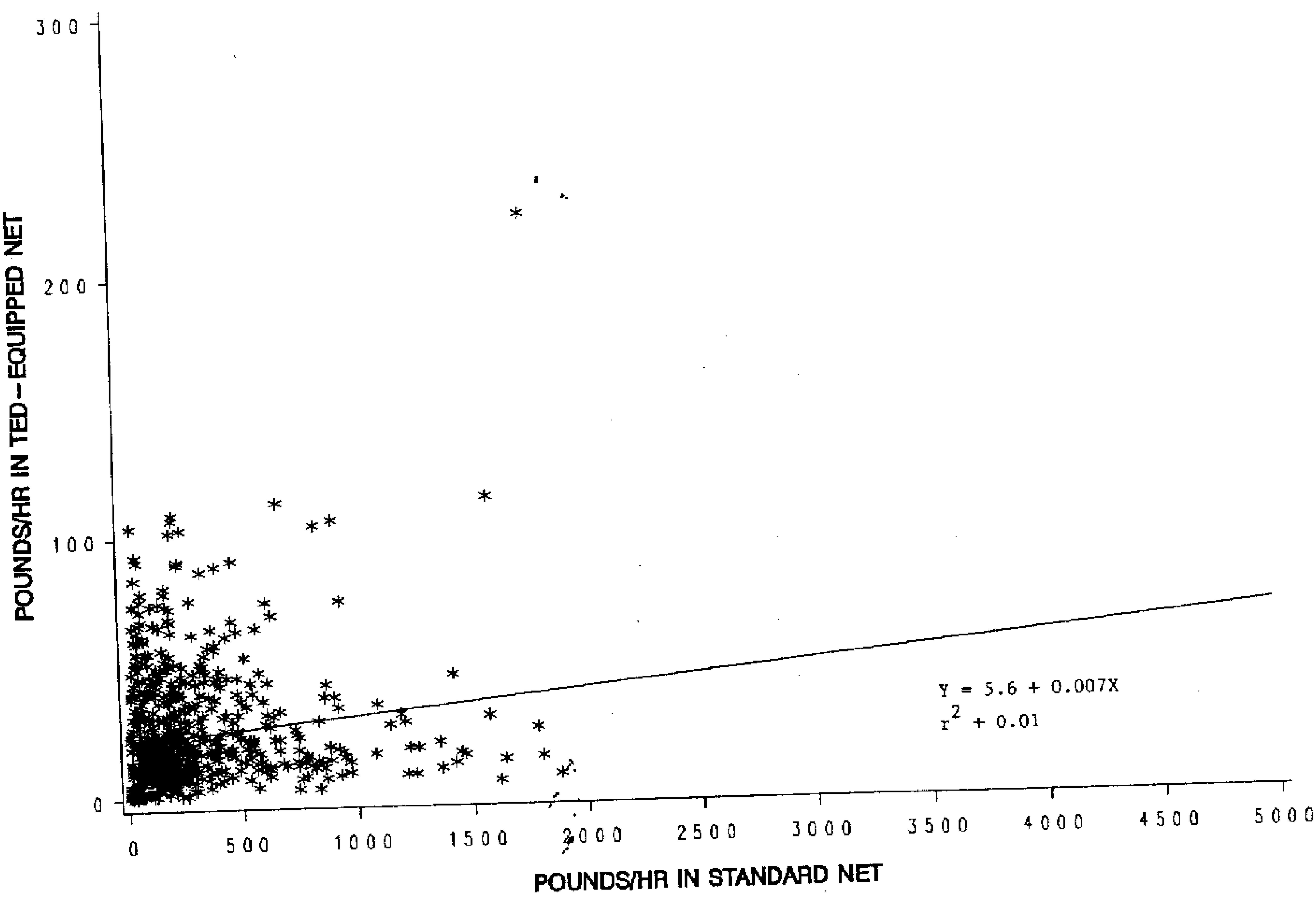


FIGURE 7. TED SHRIMP CPUE (LBS/HR) VS TED FISH CPUE (LBS/HR)
NOT ADJUSTED FOR TRY NET CATCH,
ALL AREAS/VESSELS COMBINED
N = 770

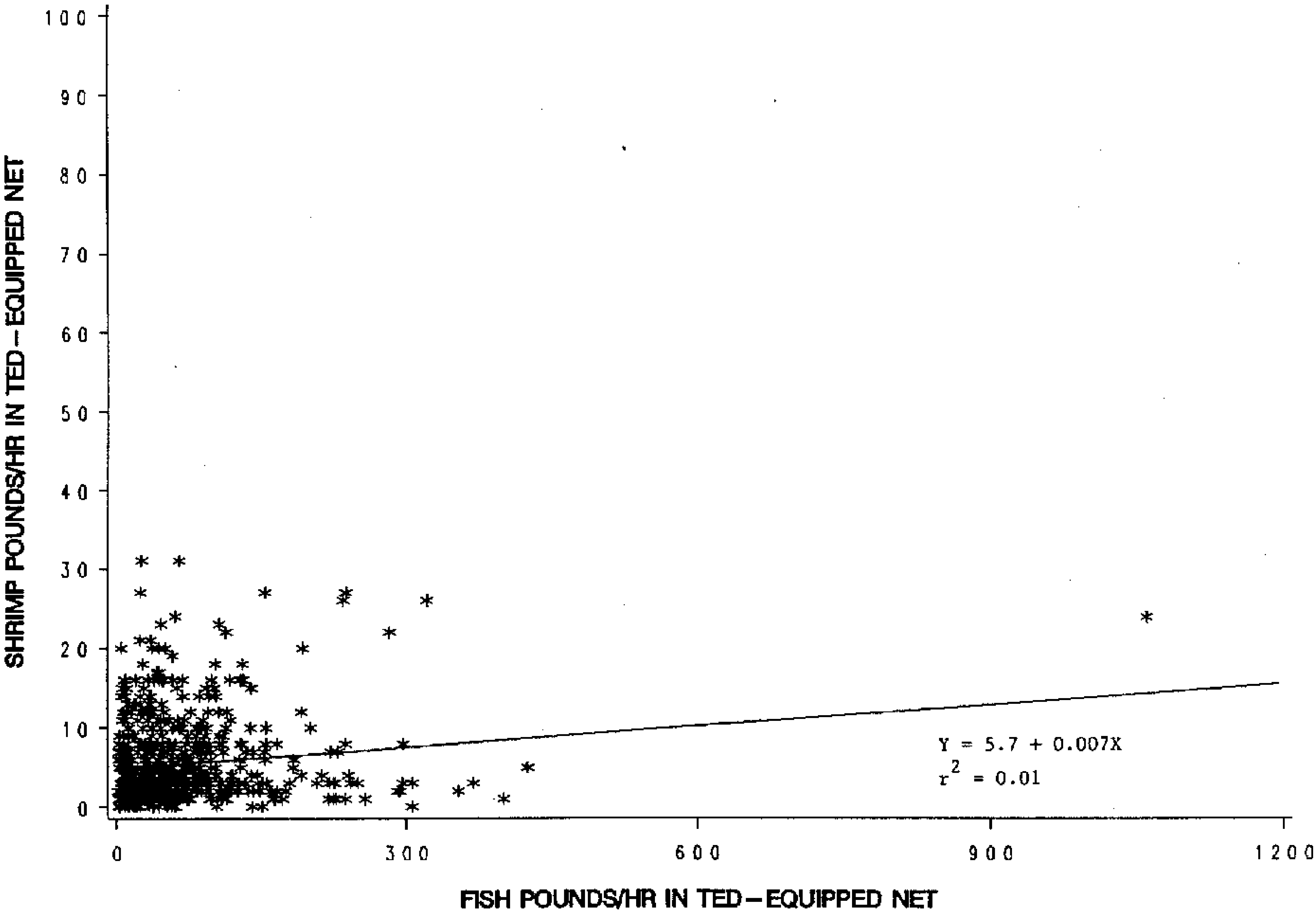


FIGURE 8. TED SHRIMP CPUE (LBS/HR) VS TED FISH CPUE (LBS/HR)
ADJUSTED FOR TRY NET CATCH,
ALL AREAS/VESSELS COMBINED
N = 770

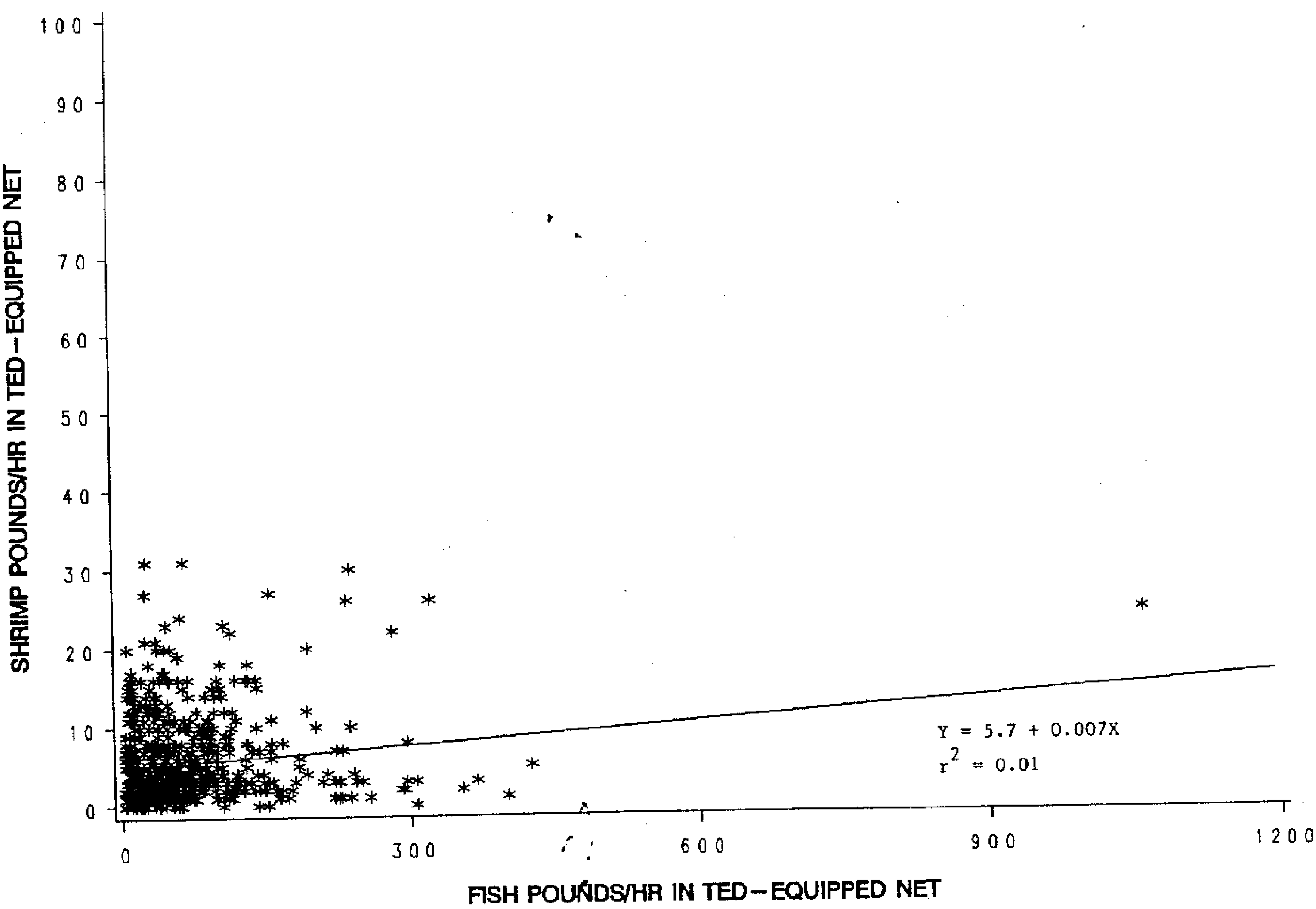


Figure 9. Locations of turtles captured during the winter.

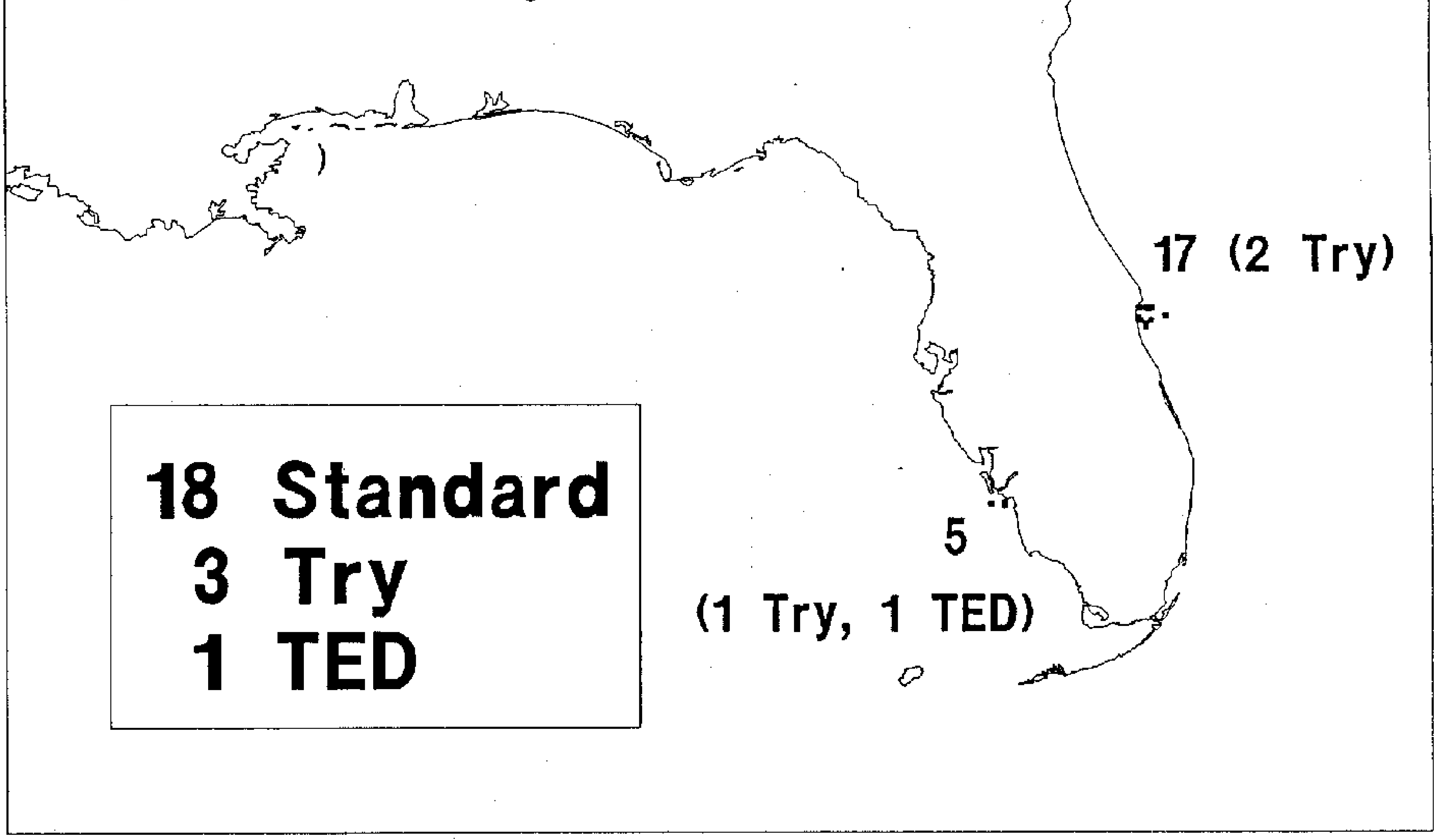
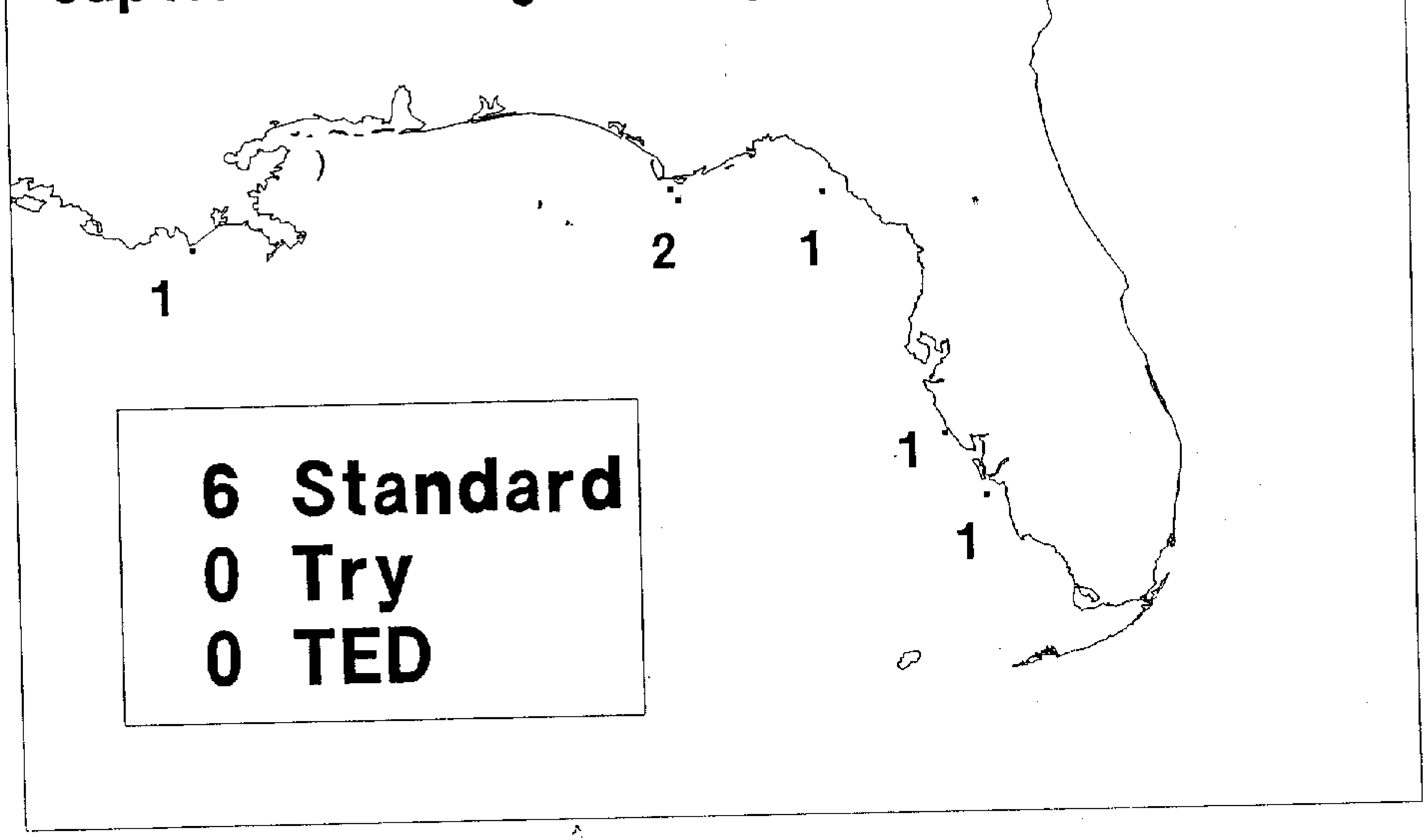


Figure 10. Locations of turtles captured during the spring.



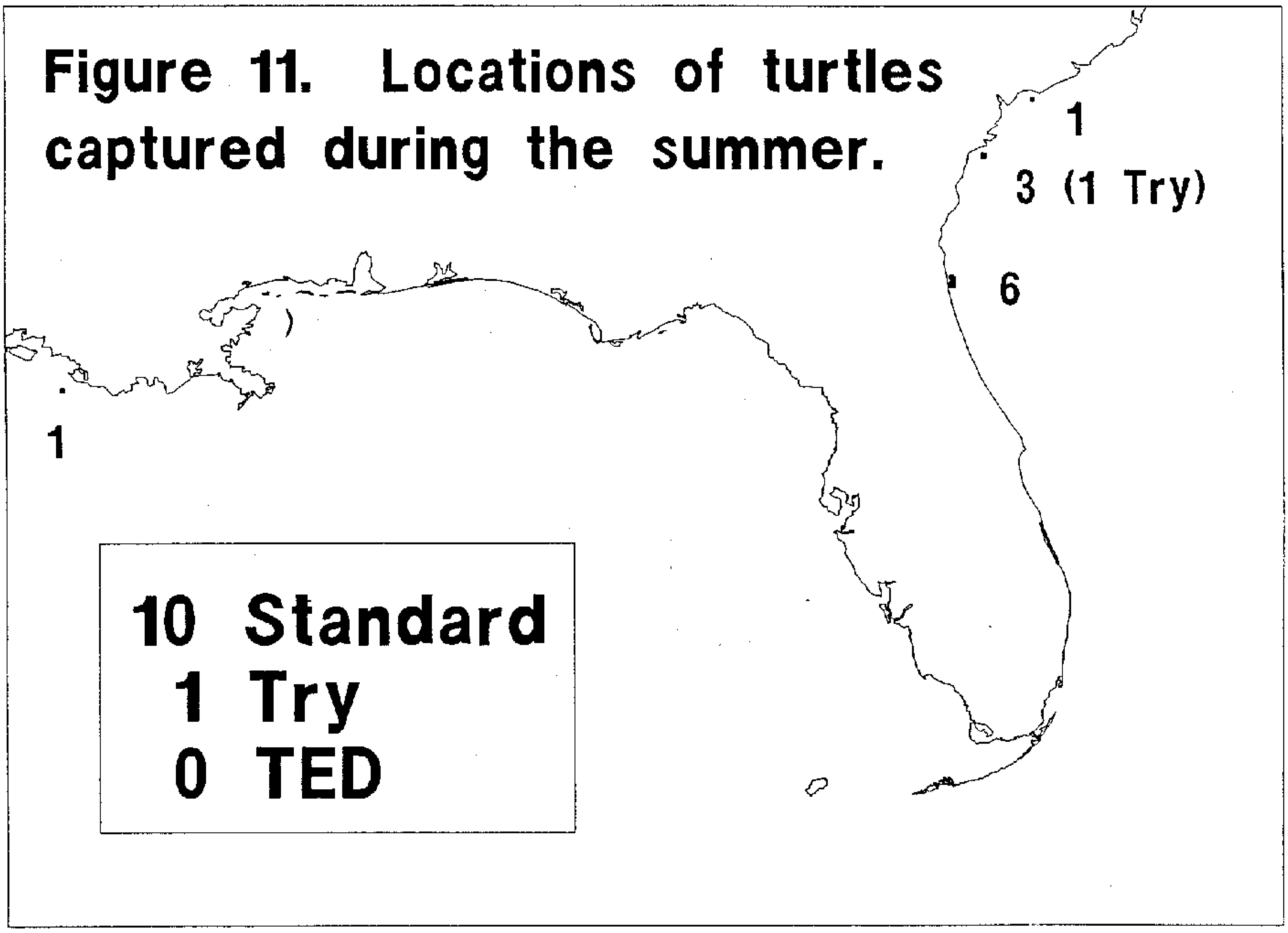


Figure 11. Locations of turtles captured during the summer.

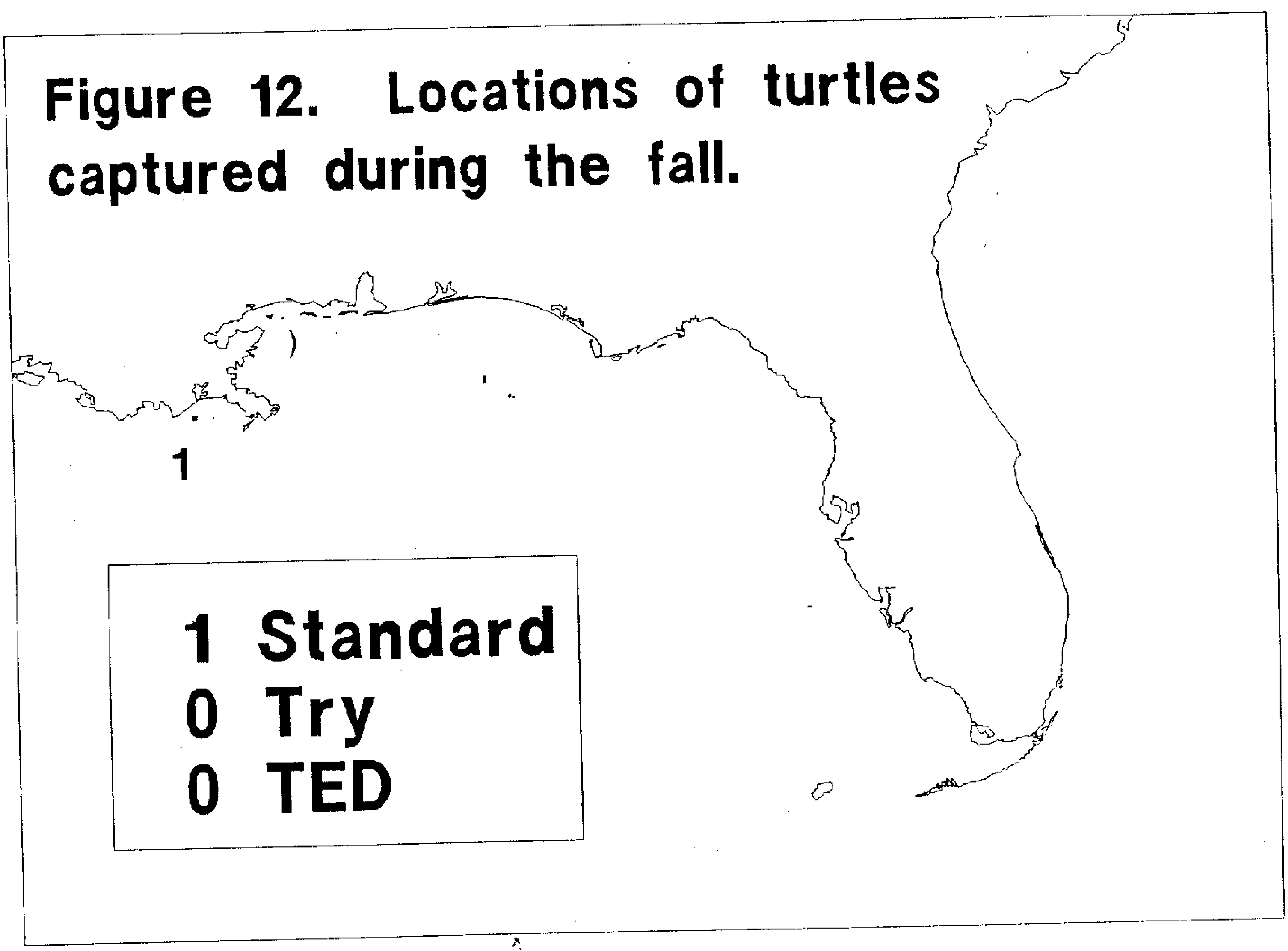


Figure 12. Locations of turtles captured during the fall.